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TRIDENT BIOLOGICAL SURVEY: JULY 1976

by

T. J. Peeling, M. H. Salazar, J. G. Grovhoug, and H. W. Goforth
Undersea Sciences Department

December 1976

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This report describes the results of a marine biological survey conducted in July 1976 at Bangor Annex (Hood Canal) of the Naval Torpedo Station, Keyport, Washington. The purpose was to assess the marine environmental effects of the early stages of construction of the Trident Submarine Support Facility. Data on environmental conditions at Bangor Annex before the beginning of construction were available from five previous surveys

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conducted between June 1973 and July 1975. The 1976 survey showed that clam abundance at each of seven stations remained relatively constant. Newly settled native littleneck clams, butter clams, and basket cockles were present in significant number at several stations, though success in reaching adult size varied from station to station. Oyster condition values of 1976 were similar to those of 1975 and indicated that no significant change in environmental quality had occurred. The byssal thread production rates of bay mussels also indicated that environmental conditions in 1976 were relatively unchanged. Otter trawl sampling at eight stations collected representatives of fourteen species of marine fishes and showed the fish population to be diverse, reproducing in significant numbers, and free of outward signs of environmental stress. The condition of eelgrass beds and piling communities also showed no signs of environmental stress at the time of the survey. It is recommended that biological surveys continue to be made as construction of the support facility proceeds.

SUMMARY

In July 1976, members of the Chemistry and Environmental Sciences Group (code 406) of the Naval Undersea Center conducted a biological assessment survey at the site of the Trident Submarine Support Facility, Bangor Annex, Naval Torpedo Station, Keyport, Washington. The primary purpose was to collect sufficient data to assess marine environmental conditions during a period of low construction activity and one year subsequent to a similar survey. The results of this survey and a comparison with previous surveys are presented in this report.

Major emphasis was placed on quantifying abundance and distribution of commercially and recreationally important species of marine molluscs and fishes that were present in the vicinity of Bangor Annex. Other faunal species and the floral components of the biota present in the area were surveyed in accordance with their relative abundance or importance in the food webs affecting the species of main concern. Specific results and recommendations are presented below. In general, it may be concluded that the marine area of Bangor Annex was little affected by the existing facility or on-going construction and was, at the time of this study, in excellent environmental condition.

Commercial clam abundance and biomass profiles developed for each of seven stations remained relatively constant. A comparison of estimated recent recruitment with abundance of adults indicated that newly settled native littleneck clams, butter clams, and basket cockles were present in significant numbers at several stations, but that the rate of success for reaching adult size varied from station to station. Oyster condition values were utilized to estimate general oyster quality and to identify areas most conducive to oyster growth. Oyster condition values of 1975 were similar to those of 1976, and indicated that no significant change in environmental quality had occurred. Monitoring the byssal thread production rates of bay mussels indicated in 1976, as in 1975, that relatively uniform water quality conditions exist along Bangor Annex. Clam population data collected by standard techniques, oyster condition values, and byssal thread production rates reflect environmental conditions and integrate stresses that may be experienced by these bivalves. Continued sampling of these biological indicators is recommended on at least an annual basis, but preferably more frequently as waterfront construction activities increase.

Otter trawl sampling conducted at eight stations along Bangor Annex collected representatives from 14 species of marine fishes. However, there were no additions to the cumulative list compiled during previous Trident surveys. It is apparent that the fishes are diverse in species composition, are reproducing in significant numbers, and show no outward signs of environmental stress. Many fish species present are highly regarded as commercially and recreationally important, and reductions in their numbers would elicit adverse public response. It is recommended that, as changes in shoreline configuration occur, fish sampling be conducted to determine the relative changes in the composition of fish populations that may also occur.

Eelgrass is present along most of Bangor Annex from approximately the zero tidal height down to approximately –15 feet. These beds support a significant amount of associated biomass in the form of microbial, infaunal, and epiphytic organisms. Eelgrass may be adversely affected by turbidity caused by dredging operations, and as a result could suffer a loss of production that could seriously affect associated organisms. Eelgrass turion density and biomass provide an indication of the response by eelgrass to changing water quality. Turion density and biomass values in this report provide baseline data from which an estimate of eelgrass response to dredging operations can be made. It is recommended that the turion density and biomass values of beds in the Bangor Annex area be monitored throughout the construction phases of the Trident facility.

Profiles of piling community species composition at Marginal Wharf and KB Pier showed no significant changes between survey periods. The new pilings at the explosives handling wharf and any additional pilings will increase the faunal diversity and biomass of their respective areas. These changes should be monitored as they occur in order to quantify their ecological impact upon the existing biological systems.

CONTENTS

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GENERAL INTRODUCTION

In 1973 the Naval Facilities Engineering Command requested that the Naval Undersea Center conduct a series of biological surveys at the proposed site of the Trident Submarine Support Facility at Bangor Annex of the Naval Torpedo Station, Keyport, Washington. The purpose was to collect data on important species of molluscs, fishes, and other forms of marine life and to form a basis for assessing the effects of construction on the marine ecosystem. As a result of this request four seasonal surveys were conducted, one each in June and October, 1973, and in January and April–May, 1974. A fifth survey was conducted in July 1975 at the request of the officer in charge of construction for the Trident facility (OICC Trident). The results of surveys I-V are documented in Naval Undersea Center Technical Publication 510 (Peeling and Goforth, 1975), and in the field data reports filed with the OICC Trident.

In 1976, the OICC Trident requested that the Center make annual biological surveys at Bangor Annex and assess the effects of construction by comparing new data with those previously collected. The results of the first of these annual surveys are presented in this report, which forms a supplement to the report cited above. At the time of the survey, conducted in July 1976, waterfront construction was just beginning, and an explosives handling wharf and piling stress testing near Devil's Hole were the only waterfront projects under way.

In conducting survey VI and presenting its results we have attempted to insure that comparison with previous surveys and their results will be meaningful and straightforward. The same species of marine life have been chosen for study, and specimens have been collected or observed at the same stations. In most instances the same methods of collection and analysis have been used. In those few instances where new methods have been introduced, the change in methodology and the reasons for it, as well as its effect on comparability of data, are noted. The format used to report the results of survey VI is the same as that used to report those of surveys I-V.

A map of the Bangor Annex area showing the location of the collecting stations is presented in figure 1. These stations have been described previously (Peeling and Goforth, 1975). An important change that affects ease of comparability should be noted: In survey VI all measurements except tidal heights have been made in metric units, even though measurements in previous surveys were made in English units.* This change has been adopted in conformity with Department of Defense policy and international scientific practice. Tidal heights are reported, as they continue to be reported in the U. S., as variations in feet from a mean lower low water level.

It should also be noted that data collected concerning the number and distribution of species at Bangor Annex during surveys I-VI have been entered in the Hawaii Coastal Zone

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**Quantitative data from previous surveys cited in this report are converted to metric units.*

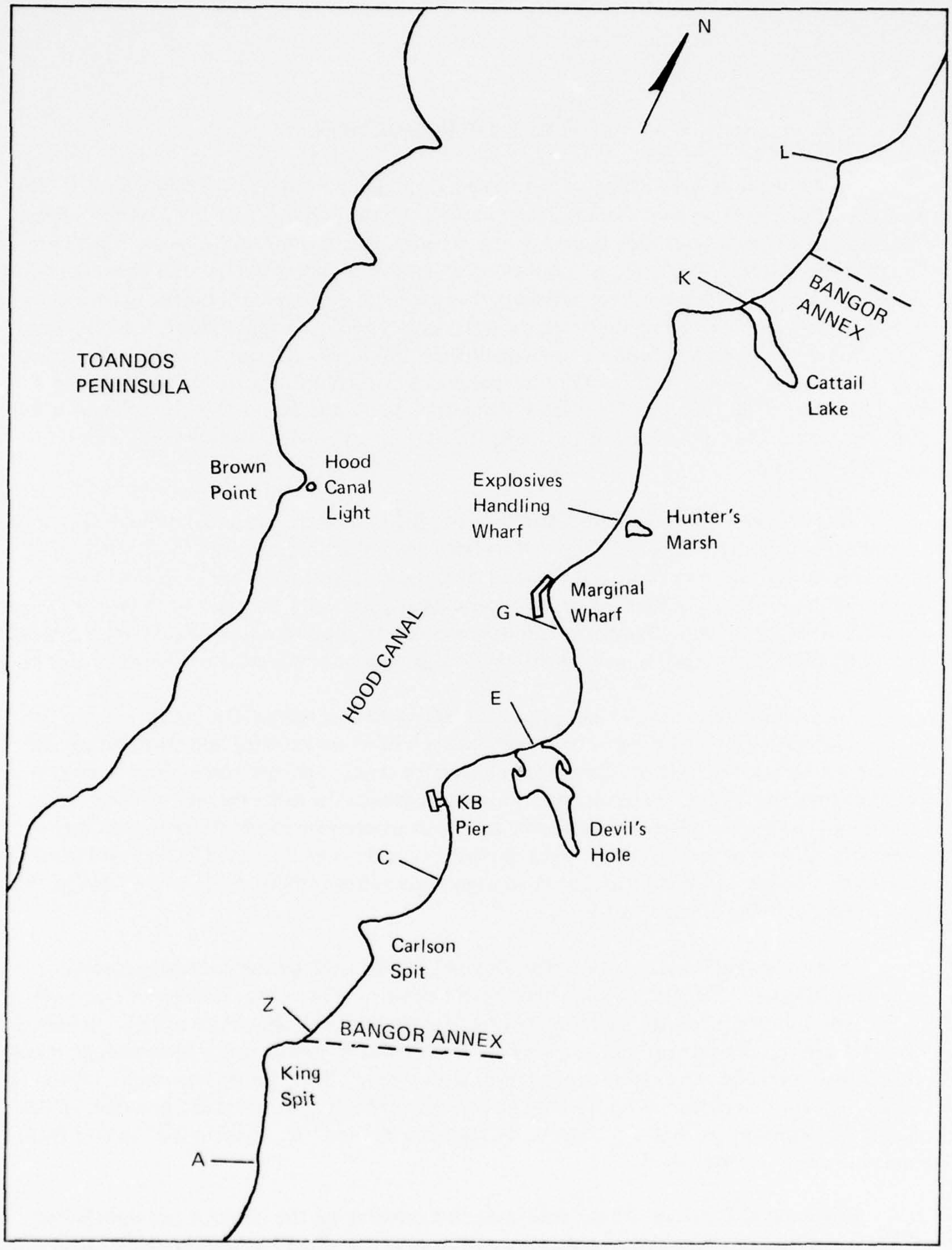

Figure 1. Map of Bangor Annex showing location of biological sampling stations.

Data Bank of the University of Hawaii. These data can be called up and reviewed by using the appropriate identification numbers, which are given on pages 43 through 58.

BIVALVE MOLLUSCS OF BANGOR ANNEX

Adult bivalves are relatively immobile or sessile and remain in a given area during most of their life span. As a result, they are directly influenced by the long-term environmental conditions of an area and may act as integrators or indicators of those conditions. However, even if bivalve populations could not be directly related to other pollution indicators, they would be studied at Bangor Annex because of their recreational and commercial importance in the Puget Sound area. Further, in terms of biomass, they dominate the intertidal zone.

This section presents data on the biology, distribution, and density of nine of the 34 species of bivalves collected during the surveys at Bangor Annex: the basket cockle (*Clinocardium nuttallii*), the native littleneck clam (*Protothaca staminea*), the butter clam (*Saxidomus giganteus*), the Japanese or Manila littleneck clam (*Venerupis japonica*), two soft shell clams (*Mya arenaria* and *M. truncata*), the Pacific oyster (*Crassostrea gigas*), the bay mussel (*Mytilus edulis*), and the geoduck (*Panopea generosa*). These data supplement those from surveys I-V. The use of data from all surveys is necessary for a proper assessment of bivalve conditions at Bangor Annex.

INTERTIDAL CLAMS OF COMMERCIAL AND RECREATIONAL IMPORTANCE

Introduction

The bivalves discussed in this subsection are basket cockles, native littleneck clams, butter clams, Japanese littleneck clams, and soft shell clams. All are considered to be commercially and recreationally important. Commercial landings of native littlenecks, butter clams, and Japanese littlenecks in Washington state have amounted to over two million pounds annually. In addition, sport clam diggers make substantial collections from intertidal populations. Because of the recreational value of the clam and oyster populations along Bangor Annex, the Navy strictly regulates and monitors bivalve collection by sportsmen.

There are a number of environmental factors which affect the abundance of intertidal clams and their distribution within geographic areas and intertidal zones. These factors must be considered in establishing baseline information to assess future environmental impact. In other words, natural variations in the ecosystem must be understood before any cause-effect relationship can be ascribed to activities by man. In view of the commercial and recreational value of intertidal clams, data have been collected since 1973 to describe size-frequency distributions, length-to-weight relationships, growth, and density profiles along Bangor Annex. The density profiles will permit sound management of clam resources along Bangor Annex and assessment of environmental impact on those resources. This section on intertidal clams concentrates on the abundance and distribution of species of commercial importance.

Materials and Methods

Intertidal digs were made at stations A, C, E, G, K, L, and Z along a transect line extending from the low tide level to the extreme high tide level.* Tidal heights were determined with a technique, first described by Emery (1961), employing two wooden poles approximately 1½ meters long, one of which was calibrated and marked at 0.125-inch (3-mm) intervals. The poles were placed vertically a known distance apart at measured intervals along the transect line, and differences in elevation were determined by aligning a sighting level on the calibrated pole with the top of the uncalibrated pole. The distance between the poles was 1½ meters on steeper slopes and 5 meters on gradual slopes. The initial measurement was made at the edge of the water at the exact time of low tide; this point was determined by using the tidal height given in the appropriate tidal table and served as the benchmark for all other tidal heights at a given station. During surveys I-V a sinusoidal equation was used to calculate tidal heights instead of the technique described here.

A minimum of one dig was made in each major intertidal zone during survey VI. Replicate digs were made in certain zones to determine the upper intertidal limit of clam populations and to develop representative density profiles. As in the previous surveys, a 0.1 m^2 quadrat was pushed into the substrate to delineate the area of the dig and prevent side wall collapse. All material down to a depth of approximately 45 cm was removed and placed in a large washtub (1 m by 1 m) with three sorting screens and no bottom. The first screen (18 mm mesh) trapped the larger clams, the second screen (6 mm mesh) most of the intermediate clams, and the third screen (2 mm mesh) the smallest clams. The third screen was used for the first time during survey VI in an attempt to quantify the recruitment of juvenile clams at the various stations. Because of the small mesh size this screen trapped large amounts of shell debris as well as small clams, making sorting more difficult and time consuming. All clams were identified as to species, measured, and counted. Commercial clams of harvestable size ($\geq$ 30 mm) were weighed on a triple beam balance to determine whether the dig was of commercial value; that is, contained 227 g/0.1 m^2 or more of commercial clams.

The density of commercial clams of each species was determined by adding the number in the commercial size range and dividing by the area sampled at each station. These data were then normalized by converting them to density per square meter. Total biomass was determined by station and species, and the data were normalized for comparative purposes as mean biomass in kilograms per square meter. The upper intertidal limit for commercial species was also determined at each station. In addition, the total number of clams in the commercial ($\geq$ 30 mm) and subcommercial ($\leq$ 30 mm) size ranges was calculated by species, dig site, and station. The subcommercial group was further subdivided by counting the number of clams 10 mm or smaller in length. This group can be considered to contain individuals having recently settled out of the planktonic stage. With these figures, the distribution of clams by species and size at each station could be compared.

Results and Discussion

The relative position and number of digs at each station are depicted in figures 2 through 8. The tidal height profiles shown in these figures represent the actual terrain at the

**The time of survey VI, like that of surveys I-V, was chosen to coincide with the lowest tides of the sampling month.*

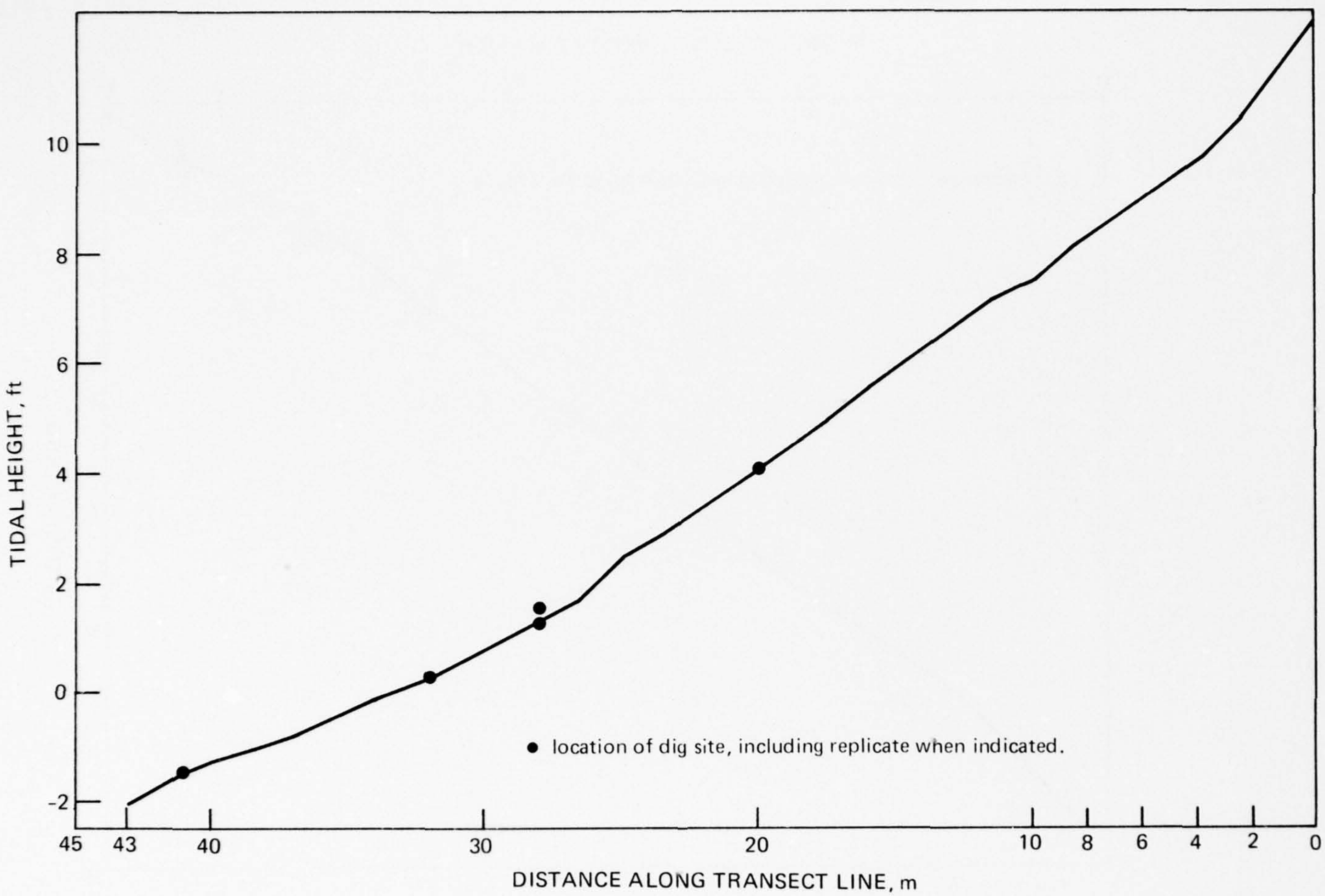

Figure 2. Beach profile at station A showing location of dig sites.

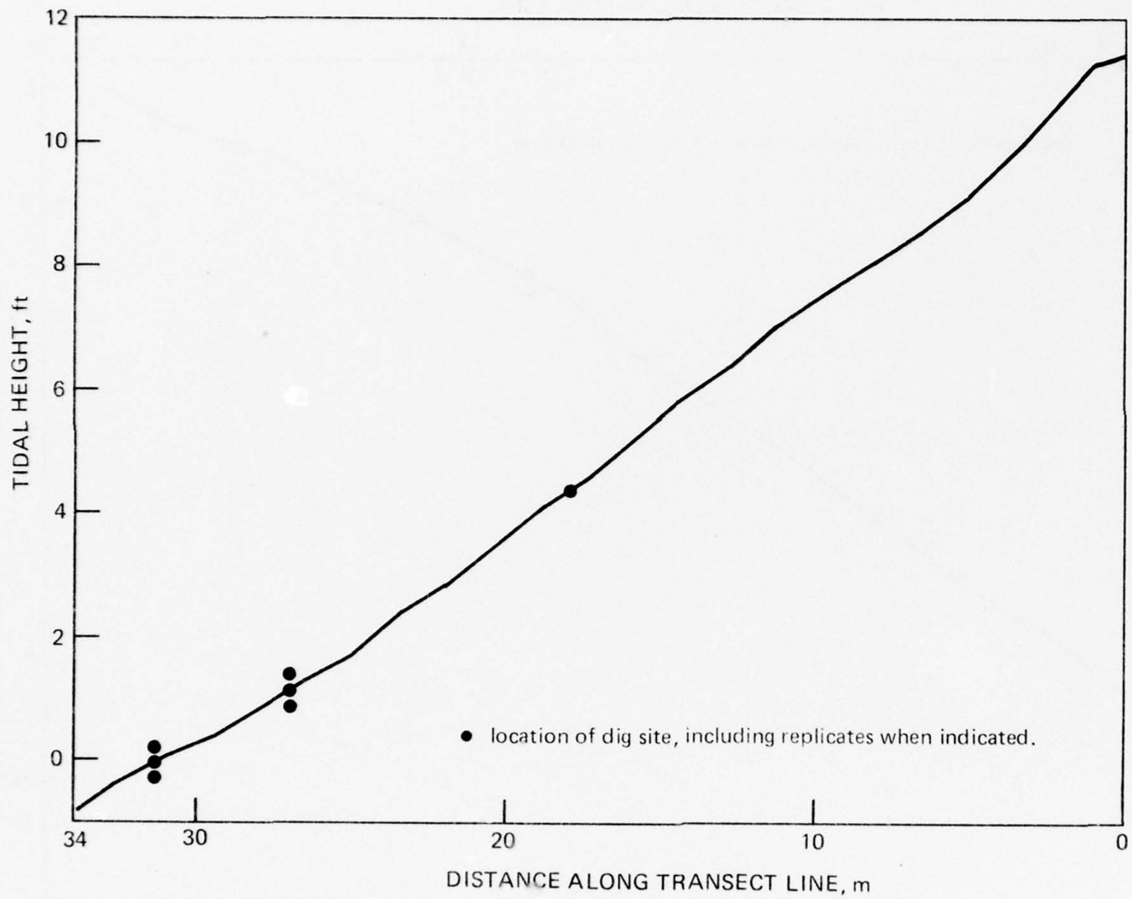

Figure 3. Beach profile at station C showing location of dig sites.

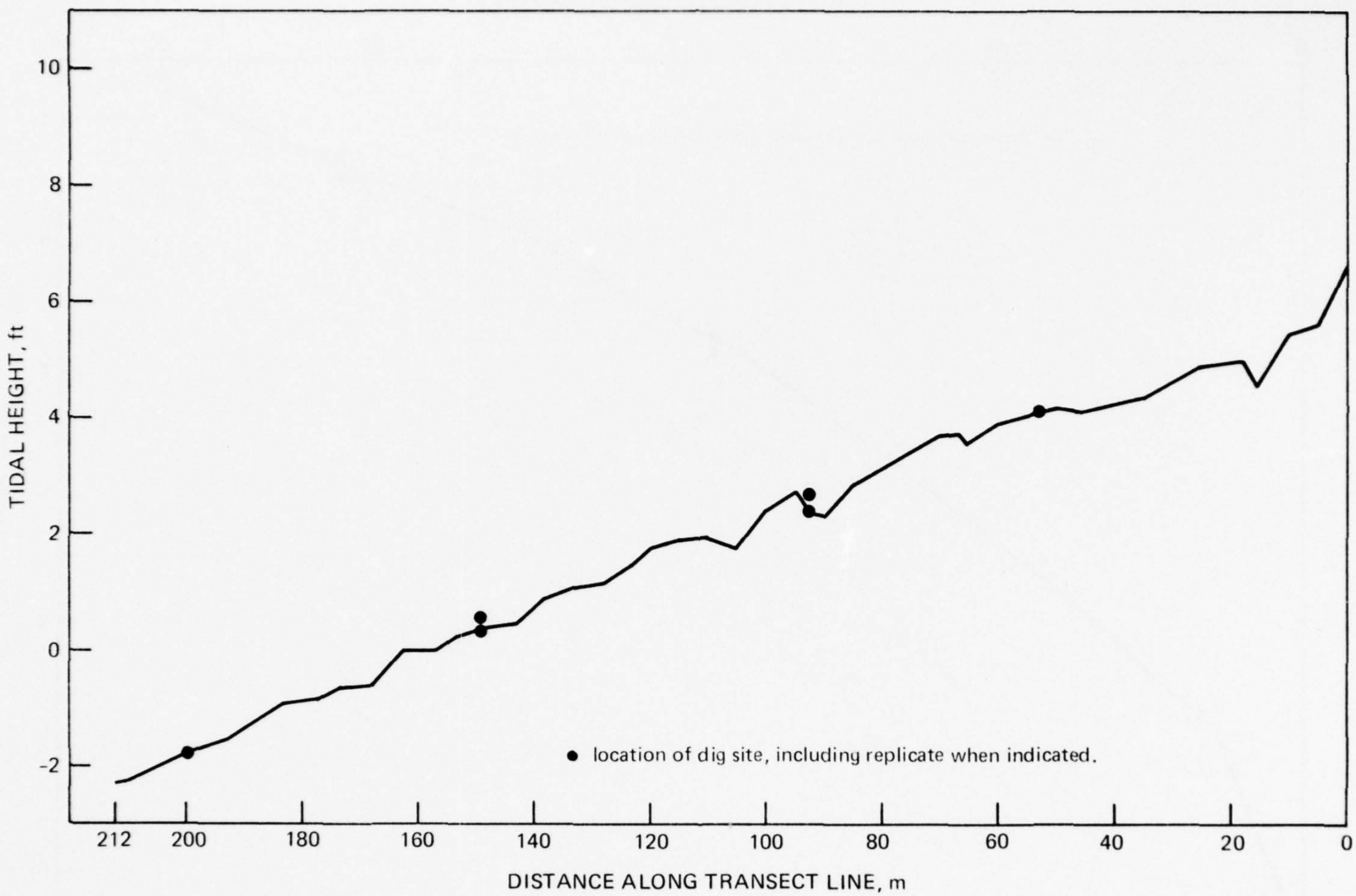

Figure 4. Beach profile at station E showing location of dig sites.

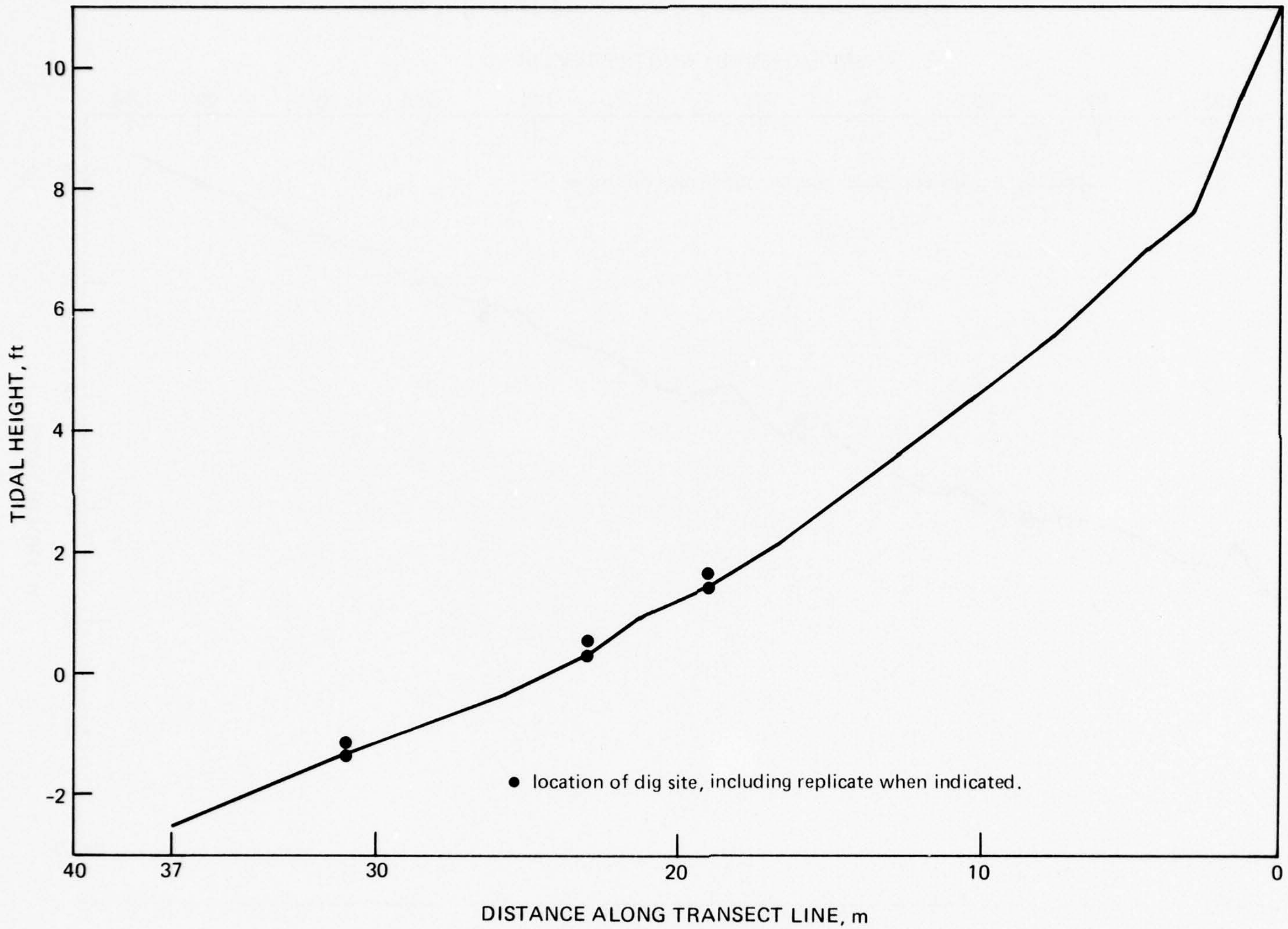

Figure 5. Beach profile at station G showing location of dig sites.

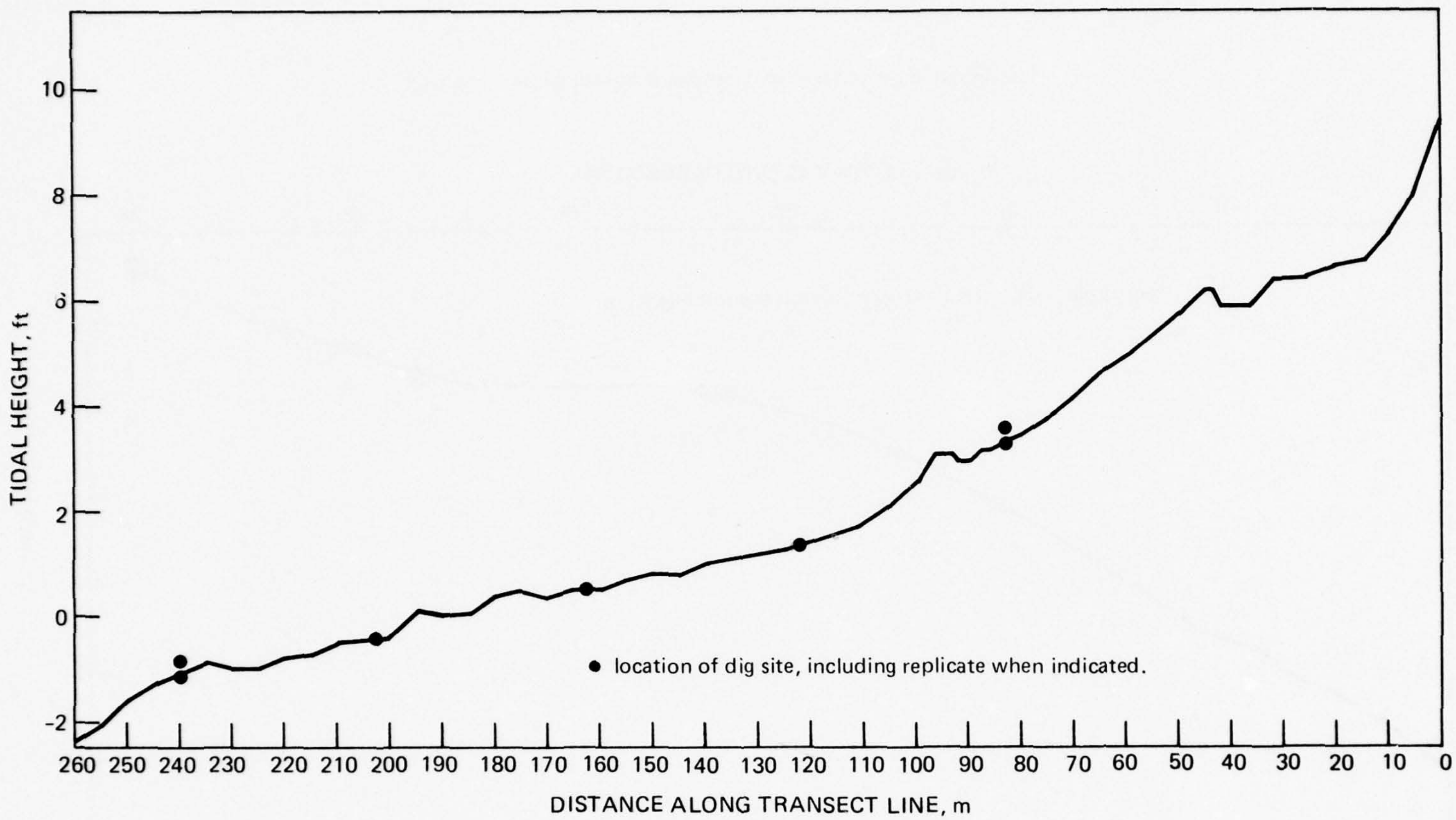

Figure 6. Beach profile at station K showing location of dig sites.

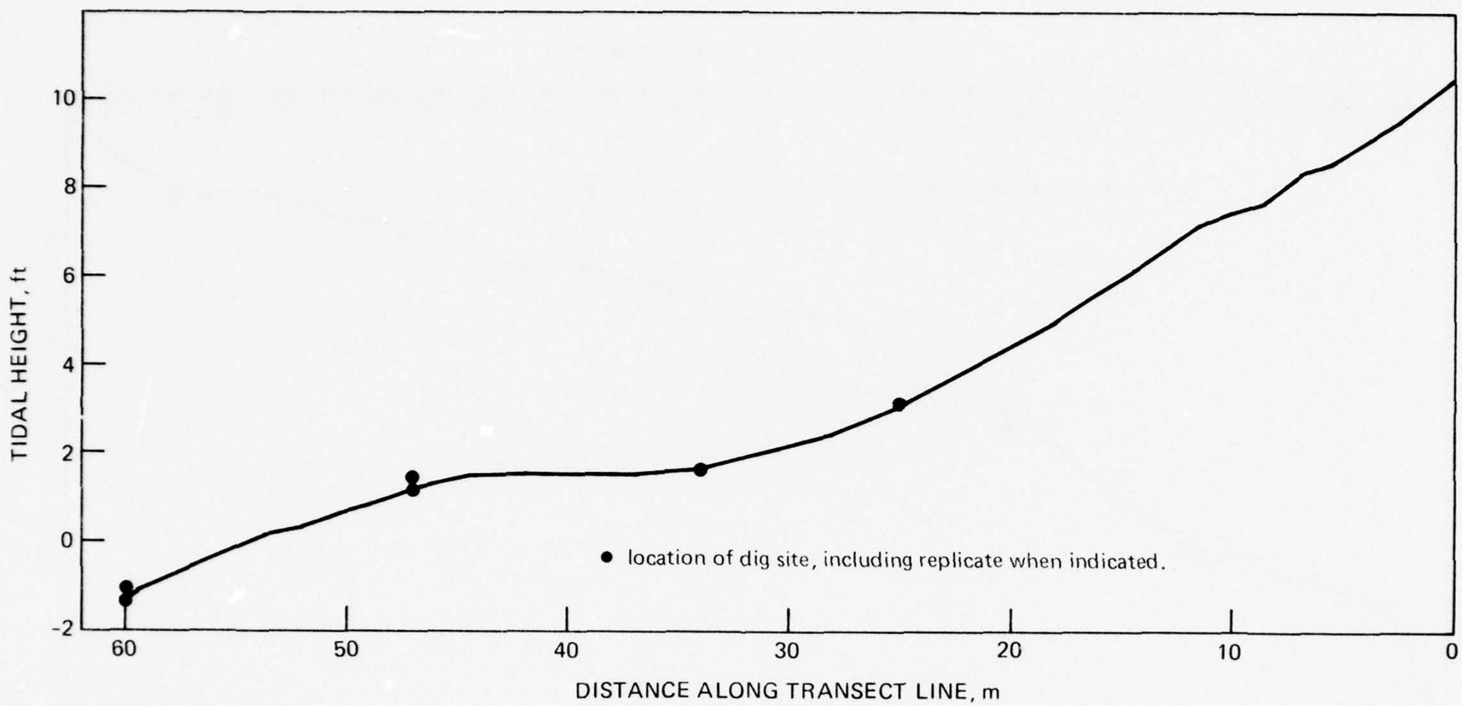

Figure 7. Beach profile at station L showing location of dig sites.

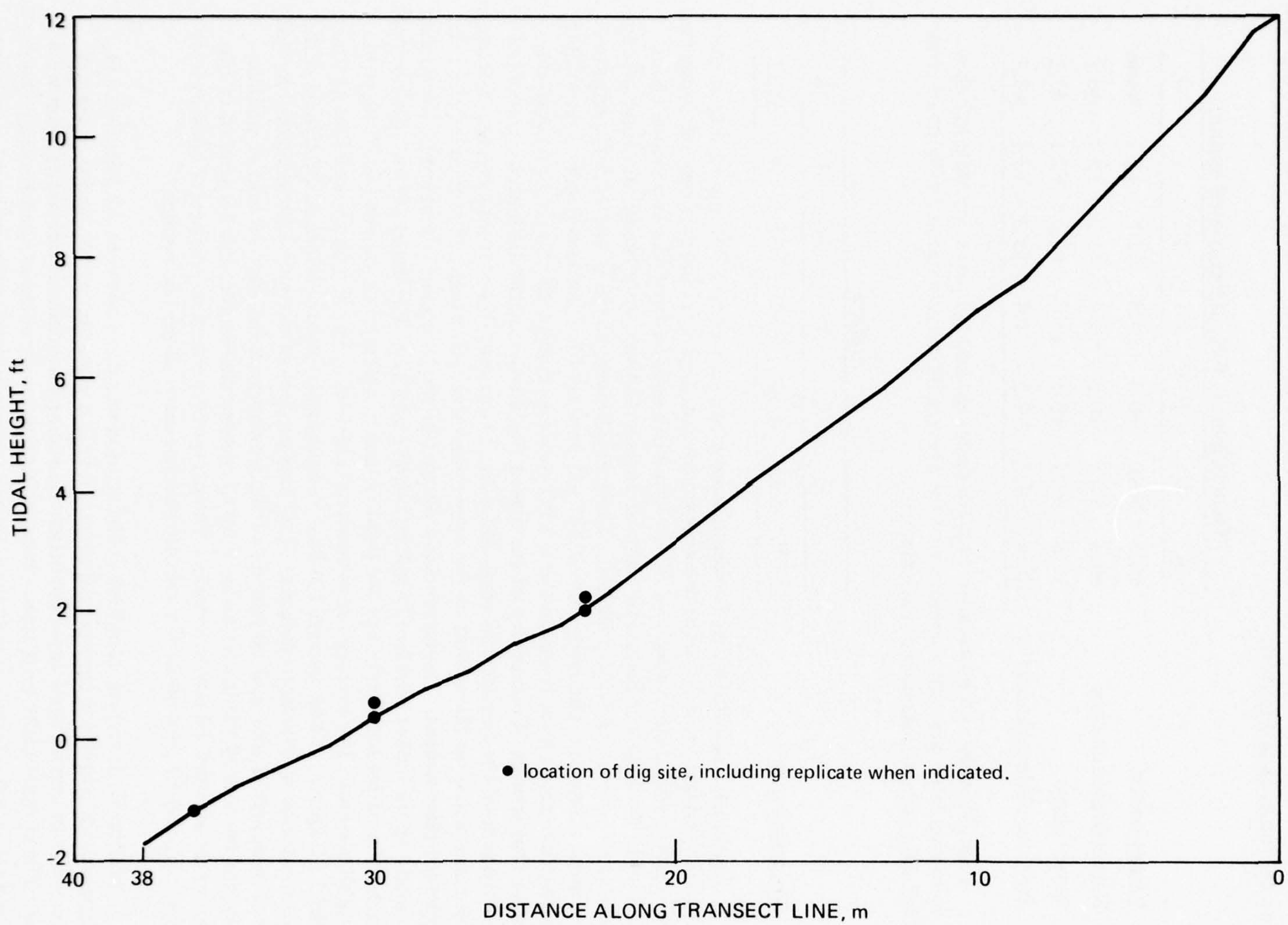

Figure 8. Beach profile at station Z showing location of dig sites.

sampling stations, and it is possible to extract a tidal height from the figure by knowing the transect line distance only. Random digs were made at each station to locate the upper intertidal limits at which commercially important bivalves were to be found. The following table shows the limits thus observed:

	Tidal height, in feet, at designated station						
	A	C	E	G	K	L	Z
Basket cockle	+0.3	None	+0.3	+0.3	+3.2	+3.1	None
Native littleneck clam	+1.3	+3.7	+0.3	+1.4	+3.2	+3.1	+4.1
Butter clam	+1.3	+4.3	+0.3	+1.4	+3.2	+3.1	+2.2
Japanese littleneck clam	None	+4.3	+2.5	-1.4	+3.2	+3.1	+3.3

Clam biomass and abundance data are described and compared by station below. The following table presents a summary of the average biomass (total live weight) of commercial clam species collected at each station:

	Station						
	A	Z	C	E	G	L	K
Biomass, kg/m^2	5.50	5.35	4.50	3.34	1.35	0.45	0.32

Station A. Intertidal digs for clams were made between +3.7 ft and -1.5 ft at station A. No bivalves were found at the uppermost site at +3.7 ft, and random digs along the transect line revealed none above +1.3 ft, where both native littlenecks and butter clams were found. No Japanese littleneck clams of commercial size were found, but nine subcommercial sized individuals were collected. Three digs between +1.3 ft and -1.5 ft each produced more clams than the minimum of 227 g/0.1m^2 set for commercial value. At +0.3 ft, 43 native littlenecks were found in the 0.1 m^2 quadrat, making this the richest of all stations for that species. Considering all the digs at this station, native littlenecks accounted for 74 percent of the commercial sized clams and 51 percent of the total biomass. The larger butter clams made up 20 percent of the commercial sized clams and 48 percent of the total commercial clam weight. The remaining 6 percent of the clams and 1 percent of the weight were made up by basket cockles (3) and soft shell clams (2). The dig at +0.3 ft was not only the richest in native littlenecks but the third richest in commercial weight (10.01 kg/m^2) among all stations. The average for commercial digs was 7.3 kg/m^2 and for all digs at this station 5.50 kg/m^2. These average biomass measurements made station A the richest of the stations in terms of commercial clams. Sixty-five percent of the native littlenecks collected were of commercial size, and 50 percent of the subcommercials were 10 mm or smaller. Thirty-one percent of the butter clams were of commercial length, and 44 percent of the subcommercials were 10 mm or smaller. Twenty-seven percent of the basket cockles were commercial, and 75 percent of the subcommercials were 10 mm or smaller.

Station C. Intertidal sampling at this station was done between +4.3 and -0.2 ft. The upper limit search for commercial species revealed none above the dig site at +4.3 ft, where one commercial sized Japanese littleneck and one subcommercial butter clam were found. The commercially important clams at station C were concentrated between the dig sites at +1.1 ft and -0.2 ft. Digs at these two sites were both of commercial value, with an average biomass of 6.6 kg/m^2. The average for all digs at this station was 4.5 kg/m^2. These

values make station C the third richest in terms of commercial clam biomass. Native littlenecks accounted for 70 percent of the commercial clams and 31 percent of the total biomass. Butter clams made up 28 percent of the number of clams collected and 66 percent of the weight. Only two Japanese littlenecks of commercial length were found at this station; they accounted for 2 percent of the commercial number and 3 percent of the weight. No basket cockles or soft shell clams were found of either commercial or subcommercial size. Seventy-five percent of the native littlenecks collected were of commercial size, and 25 percent of the subcommercials were 10 mm or smaller in length. Seventy-seven percent of the butter clams were in the commercial group, and 43 percent of the subcommercial group were 10 mm or smaller.

Station E. Intertidal digs were made between +4.1 ft and −1.8 ft. No clams were found at +4.1 ft. One subcommercial sized Japanese littleneck clam was found at +2.5 ft. No native littlenecks or butter clams were found above a tidal height of +0.3 ft. Digs at +0.3 and −1.8 ft were of commercial value, with an average biomass of 6.9 kg/m^2. The dig at −1.8 ft produced 12 large butter clams and was the second largest in biomass (10.5 kg/m^2) of any station sampled. The 22 butter clams collected at station E were all of commercial size and accounted for 50 percent of the number and 90 percent of the total weight of commercial clams collected at this station. Native littlenecks accounted for 23 percent of the number of commercial clams and 9 percent of the weight. Only 10 percent of the native littleneck clams collected were of commercial size, and 43 percent of the subcommercial sized individuals were less than 10 mm in length. Soft shell clams made up 18 percent and basket cockles 9 percent of the commercial clams collected, but together they made up only 1 percent of the weight. Station E ranked in the middle of all stations, with a mean biomass of 3.34 kg/m^2.

Station G. Station G followed station E in terms of richness with an average biomass for commercial species of 1.35 kg/m^2. Samples were taken between +1.4 ft and −1.4 ft. The upper limit was +1.4 ft for both butter clams and native littlenecks, although the butter clams found at this height were not of commercial size. Commercial butter clams did not appear above a tidal height of −1.4 ft. Surprisingly, −1.4 ft was also the upper limit for Japanese littlenecks, but even these were not of commercial size. No commercial sized Japanese littlenecks and only two of subcommercial size were found at this station. The only dig of commercial value was at −1.4 ft. The density at this site was 2.64 kg/m^2, and the average for all digs was 1.35 kg/m^2. Butter clams, soft shell clams, and basket cockles each represented 27 percent of the commercial clam population; butter clams represented 62 percent, soft shell clams 17 percent, and basket cockles 13 percent of the total weight. Native littlenecks accounted for 18 percent of the total number of commercial clams and 8 percent of the total weight. Of the nine native littlenecks, only two were of commercial length. Of the seven butter clams collected, three were of commercial length. Twenty-five basket cockles were found at this station, only three of which (12 percent) were of commercial length. The group of basket cockles 10 mm or less in length accounted for 84 percent of the subcommercials.

Station K. Intertidal digs were made at this station between +3.3 ft and −1.1 ft. The upper limit for butter clams, native littlenecks, and Japanese littlenecks was +3.3 ft. A random search along the transect line revealed no clams above the dig at +3.3 ft. Although this dig was not of commercial value, it was the only site where a significant number of commercial clams was found. Only one clam of commercial size was found below +3.3 ft. This was

the poorest of all stations, with an average biomass of 0.32 kg/m^2. A total of only 10 commercial clams was collected: four native littlenecks, two butter clams, one Japanese littleneck, one soft shell clam, and two basket cockles. Eighty percent of the native littlenecks were in the subcommercial group, and 25 percent of these were 10 mm or smaller in length. Ninety-seven percent of the Japanese littlenecks were in the subcommercial group, and 67 percent of these were 10 mm or smaller in length. Ninety-six percent of the basket cockles were in the subcommercial group, and all were 10 mm or smaller in length.

Station L. In terms of commercial clam biomass, station L was comparable to station K, with an average of 0.45 kg/m^2. Only two clams of commercial size were collected, but they were large heavy butter clams. Intertidal digs were made between +3.3 ft and −1.3 ft. No commercial clams were found at the uppermost site. Native littlenecks, Japanese littlenecks, and butter clams were found at a height of +3.1 ft, though none was of commercial length. The two commercial sized butter clams mentioned were found at −1.3 ft. Only six native littlenecks, six butter clams, and two Japanese littlenecks in the subcommercial group were found. A total of 34 subcommercial basket cockles was found, all of which were 10 mm or smaller.

Station Z. Station Z ranked second to station A in average biomass of commercial clams at 5.35 kg/m^2. Intertidal digs at station Z were made between +2.2 ft and −0.9 ft. The upper limit search revealed native littlenecks at +4.1 ft and Japanese littlenecks at +3.3 ft, but butter clams were not found above +2.2 ft. Two Japanese littlenecks of commercial size were also found at the +2.2 ft site. At +0.4 ft the largest commercial dig for all stations was recorded. A total of 12 native littlenecks and 14 butter clams of commercial size produced a biomass of 11.9 kg/m^2 at this site. The dig at −0.9 was also of commercial value at 2.58 kg/m^2. Native littlenecks made up 50 percent of the number of commercial clams and 14 percent of the weight at this station. Butter clams accounted for 45 percent of the commercial clams and 85 percent of the weight. Two Japanese littlenecks made up the balance, with 5 percent of the total number and 1 percent of the weight. Only one subcommercial butter clam and four subcommercial Japanese littlenecks were found. No basket cockles or soft shell clams were found at this station. Fifty-one percent of the native littlenecks were in the commercial size group, and of the subcommercials 11 percent were 10 mm or smaller in length.

A total of 42 intertidal digs were made at the seven stations. These digs produced 269 clams of commercial species and commercial size, with a total weight of 7.24 kg. The numerically dominant commercial clams were native littlenecks at 57 percent, representing 26 percent of the total weight. Butter clams were the next most abundant at 32 percent of the total number, with 68 percent of the total weight. Only five of the 269 commercial sized clams were Japanese littlenecks, and their weight accounted for less than 1 percent of the total. Soft shell clams (*Mya arenaria*) and basket cockles represented only about 3 percent each of the total weight.

Of the 42 digs, 17 were considered of commercial value, and 13 of these were at stations A, C, and Z. At these stations, the commercial digs were grouped between +1.3 and −1.5 ft. Within that range the native littlenecks were more abundant than butter clams, but the butter clams contributed more to the total weight because of their large size. Most of the native littlenecks were found in the uppermost portion of that range, with a decrease in abundance near the lower end. Butter clams, on the other hand, increased in abundance

with decreasing tidal height in the range of the commercial digs. Figure 9 shows average density in number per square meter by station and species for commercial species and sizes. Table 1 shows the distribution of commercial clams of all sizes by species, station, and tidal height. Japanese littlenecks are not included in either the figure or the table because only five in the commercial size range were found.

Native littlenecks were most abundant at stations A and C, which had similar densities of 112 and $100/m^2$ respectively. Station Z had only about 40 native littlenecks per square meter, and the other stations had fewer. Butter clams were most abundant at station C with $40/m^2$; stations A, E, and Z were comparable with 30, 37 and $36/m^2$. Soft shell clams and basket cockles were not present in commercial sizes at stations C and Z and only in small numbers at the other stations.

Average biomass by station and species is shown in figure 10 for commercial species and sizes. By comparing figures 9 and 10, the relative contribution to the total biomass of each species at each station can be determined. At station A, for example, there are almost four times as many commercial sized native littlenecks per square meter as butter clams, and yet butter clams contribute just about as much to the average biomass. At station Z the number of native littlenecks and butter clams is about the same for every square meter sampled, and yet the biomass of the butter clams is on the average about four times greater. At station C the number of native littlenecks was about 2.5 times greater on the average, but the butter clams contributed about twice as much to the average biomass.

Ranked in order of decreasing commercial clams biomass per unit area, the stations are A, Z, C, E, G, L, and K. As shown in figure 1, this is the approximate order of the stations as one proceeds from south to north in Hood Canal. The stations can also be grouped in terms of relative clam weight per unit area: Stations A, Z, and C are in the richest group, G and E in the middle, and L and K in the poorest.

Considering all stations, a total of 341 native littlenecks, 60 Japanese littlenecks, 152 butter clams, 19 soft shell clams, and 130 basket cockles were collected during this survey. Forty-five percent of the native littlenecks were in the commercial size range, and 39 percent of the subcommercials were 10 mm or smaller in length. Only 8 percent of the Japanese littlenecks were considered commercial, and 44 percent of the subcommercials were 10 mm or smaller in length. Fifty-seven percent of the butter clams were commercial, and in the subcommercial group 42 percent were 10 mm or smaller. No soft shell clams 10 mm or smaller were found at any of the stations, but 14 commercials and 5 subcommercials larger than 10 mm were found. Only 9 percent of the basket cockles were of commercial length, and 89 percent of the subcommercials were 10 mm or smaller in length. Since the group 10 mm or smaller is indicative of recently set animals, heavy recruitment of basket cockles was evident at stations G, L, and K, accounting for 94 percent of all basket cockles in that size range. Heavy recruitment of native littlenecks was evident at station E, where 53 percent of all juveniles 10 mm or smaller were found. At station K, 22 of the 24 Japanese littlenecks collected were 10 mm or smaller.

Conclusions

In July 1976, sampling was conducted at seven intertidal stations in the vicinity of Bangor Annex to determine the relative species composition, density, and biomass of

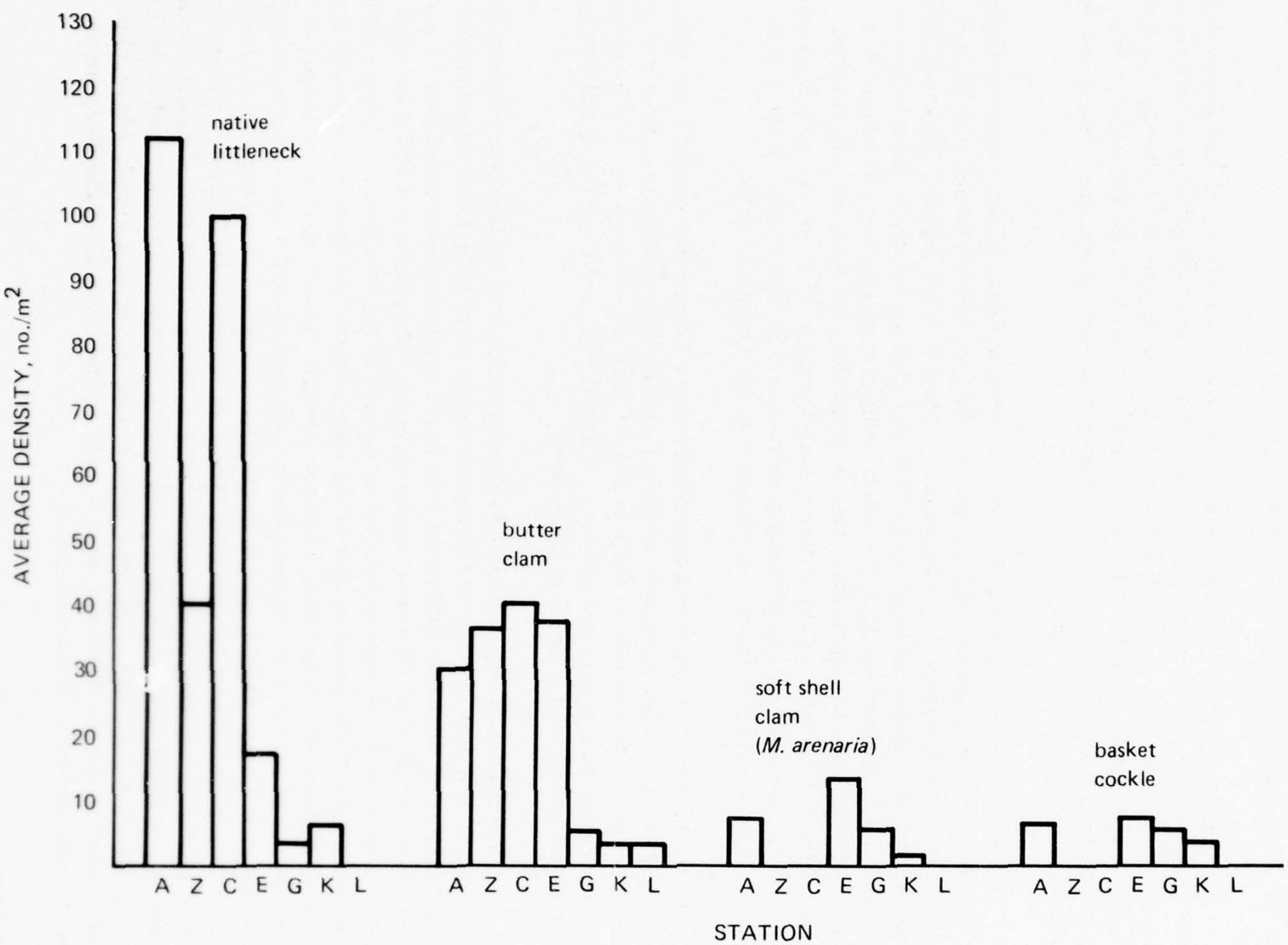

Figure 9. Clam density by station and species (commercial species and sizes only).

Table 1. Clam distribution by station, species, and tidal height (commercial species only).

	Number of commercial (subcommercial) sized individuals per 0.1 m^2 at designated dig site				
Station A	4.2 ft	1.3 ft	0.3 ft	-1.5 ft	
Native littleneck	0 (0)	5.5 (2)	43 (9)	2 (17)	
Butter clam	0 (0)	4.5 (3)	2 (13)	4 (15)	
Soft shell clam (*M. arenaria*)	0 (0)	0.5 (0)	1 (1)	0 (0)	
Basket cockle	0 (0)	0 (0)	3 (4)	0 (4)	
Station C	4.3 ft	1.1 ft	0.0 ft		
Native littleneck	0 (0)	13 (6.7)	10.3 (0)		
Butter clam	0 (1)	3.3 (2)	4.7 (0.3)		
Soft shell clam (*M. arenaria*)	0 (0)	0 (0)	0 (0)		
Basket cockle	0 (0)	0 (0)	0 (0)		
Station E	4.1 ft	2.5 ft	0.3 ft	-1.8 ft	
Native littleneck	0 (0)	0 (0)	4 (27)	2 (37)	
Butter clam	0 (0)	0 (0)	5 (0)	12 (0)	
Soft shell clam (*M. arenaria*)	0 (0)	4 (2)	0 (0)	0 (0)	
Basket cockle	0 (0)	0 (0)	0.5 (2.5)	3 (5)	
Station G	1.4 ft	0.3 ft	-1.4 ft		
Native littleneck	1 (0.5)	0 (1)	2 (2)		
Butter clam	0 (0.5)	0 (0)	3 (1.5)		
Soft shell clam (*M. arenaria*)	0.5 (0)	1 (0)	3 (0)		
Basket cockle	0 (0)	1 (8)	3 (3)		
Station K	3.2 ft	1.3 ft	0.5 ft	-0.4 ft	-1.1 ft
Native littleneck	2 (7)	0 (0)	0 (0)	0 (0)	0 (1)
Butter clam	1 (3)	0 (0)	0 (0)	0 (0)	0 (4)
Soft shell clam (*M. arenaria*)	0.5 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Basket cockle	0.5 (0.5)	0 (2)	0 (6)	0 (27)	1 (4)
Station L	3.1 ft	1.6 ft	1.2 ft	-1.3 ft	
Native littleneck	0 (2)	0 (2)	0 (1)	0 (0)	
Butter clam	0 (3)	0 (1)	0 (0)	1 (1)	
Soft shell clam (*M. arenaria*)	0 (0)	0 (0)	0 (0)	0 (0)	
Basket cockle	0 (1)	0 (1)	0 (15)	0 (1)	
Station Z	2.2 ft	0.4 ft	-1.2 ft		
Native littleneck	3.5 (8)	6 (1.5)	1 (0)		
Butter clam	1.5 (0.5)	7 (0)	1 (0)		
Soft shell clam (*M. arenaria*)	0 (0)	0 (0)	0 (0)		
Basket cockle	0 (0)	0 (0)	0 (0)		

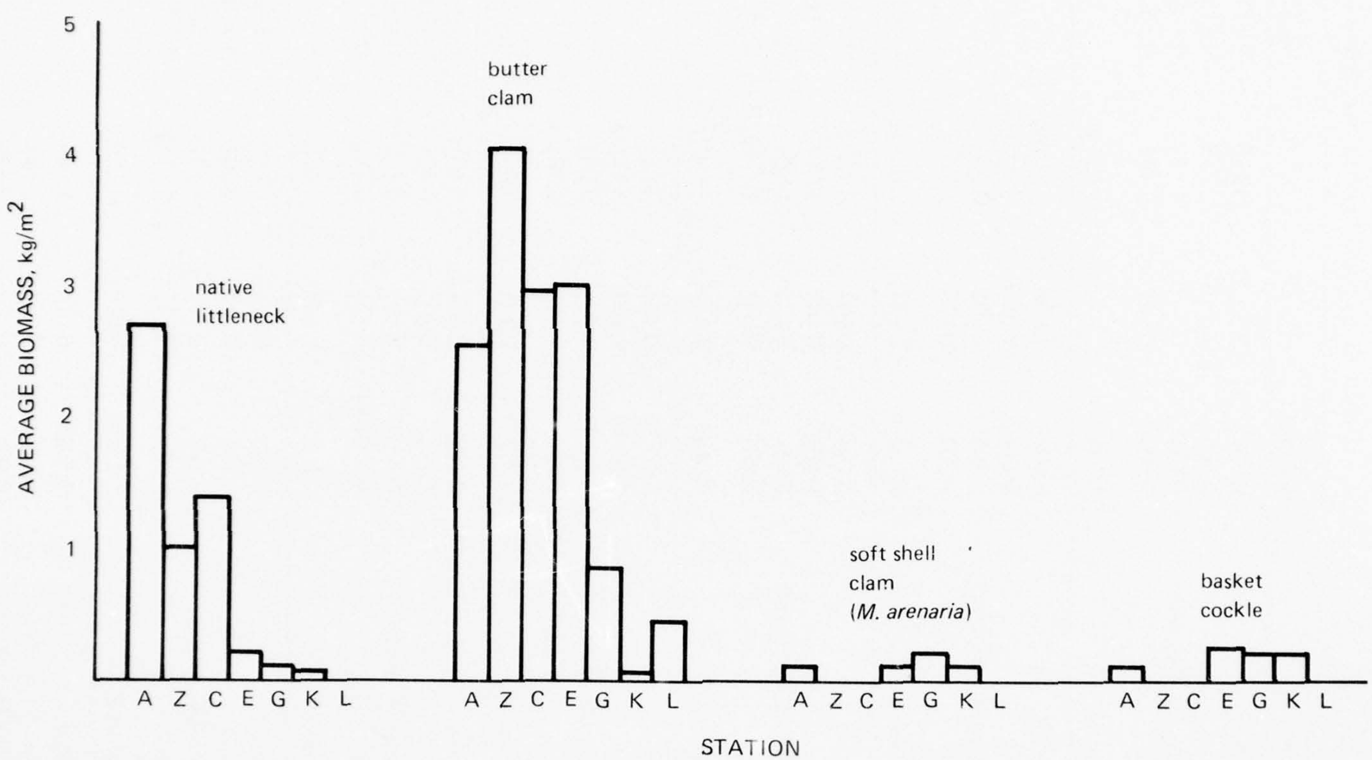

Figure 10. Clam biomass by station and species (commercial species and sizes only).

commercially and recreationally important species of bivalves. The following conclusions are presented as a general summary of the results of this sampling effort:

1. In order of decreasing abundance, the following commercial clams were sampled in the intertidal zone of Bangor Annex: native littlenecks, butter clams, soft shell clams, basket cockles, and Japanese littlenecks.

2. Native littlenecks, butter clams, and Japanese littlenecks appear to have their upper limits in the intertidal zone at approximately +4.3 ft. The upper limit for basket cockles is +3.2 ft.

3. The relative biomass of commercial clams per unit area can be used to rank the stations in the following decreasing order: A, Z, C, E, G, L and K.

4. Stations A, Z, and C included the most substantial commercial digs; digs at station A showed the greatest variation with tidal height (+1.3 to −1.5 ft).

5. If the commercially important species are ranked in descending order by their contribution to the total biomass at all stations, their relative positions are as follows: butter clams, native littlenecks, soft shell clams, basket cockles, and Japanese littlenecks.

6. Station E data indicated a substantial recruitment of native littlenecks (39 percent of total collected), but the number of individuals larger than 30 mm was low, indicating high juvenile mortality or, more likely, heavy recreational clam digging. Relative recruitment of native littlenecks at stations A, C, and Z is lower than at station E, but a much higher success rate for reaching adult size is indicated (little recreational clam digging is done at these stations).

7. Initial recruitment and juvenile success rates for butter clams appeared high at stations A and C, but stations E and Z showed low recruitment.

8. Recruitment appeared to be particularly good for basket cockles at stations G, K, and L, where an average of 94 percent of that species was 10 mm or smaller.

OYSTER CONDITION INDICES

Introduction

The general condition of oysters is considered by many investigators to be an indicator of recent or existing environmental conditions. Quayle (1969) presents several case studies where oyster condition data were useful not only in managing oyster stocks but also in evaluating environmental quality. Most investigators agree, however, that there are limitations on the application of oyster data and that adequate baseline data are necessary before oyster condition and environmental quality can be properly correlated.*

During survey VI the problem of using oyster condition indices as a measure of environmental quality was discussed with R. Westley of the Point Whitney Shellfish Laboratory, Washington Department of Fisheries. It was generally agreed that the indices reflect the effects of environmental factors, but that there is a problem in separating normal and abnormal responses; normal weight loss after spawning and low condition index values during early winter, for example, must not be confused with similar responses caused by increases in water turbidity or the presence of toxicants. It was further agreed that, with sufficient

Refer to Peeling and Goforth, 1975, page 29.

seasonal data collected during construction at Bangor Annex, abnormal responses by oysters to changes in water quality could be detected from condition index values. Therefore, oyster sampling was continued as part of the annual assessment of biological conditions at Bangor Annex, and a program of more frequent sampling was proposed and is under study. The results of the July 1976 survey are presented in this section.

Materials and Methods

The materials and methods used during survey VI were the same as those used during previous Trident surveys. A sample of 10 oysters (*Crassostrea gigas*) was collected from the intertidal zone at approximately the +2.5-ft tidal level from stations C, E, K, Z and Toandos Peninsula. The Toandos Peninsula station, located approximately 400 meters south of Brown Point, was chosen as a control site because it appeared least exposed to man-made perturbations. To minimize individual variability, collections were limited to oysters between 90 and 102 mm in length.

Following collection, the oysters were transported to the laboratory and placed in a bucket of sea water for 30 minutes. This procedure eliminated errors that could be caused by air trapped inside the valves. The shells were brushed to remove barnacles and debris, and the total volume determined by water displacement in a graduated cylinder. The oysters were then opened and the meats removed by severing only the adductor muscle. The meats were then gently blotted and wet weights determined to the nearest 0.1 gram. The two shell halves were wiped clean, and their volume determined by water displacement in a graduated cylinder. The volume of the internal shell cavity was calculated by subtracting the volume of the two shell halves from the total shell volume. Oyster meats were severed with a scalpel to facilitate drying and then placed in tared aluminum foil boats. Meats were dried at 100°C for 24 hours and weighed on an analytical balance accurate to the nearest 0.001 gram.

The index used to evaluate the oyster condition was the modified condition index (MCI), described by Katkansky et al. (1967),

$$\text{MCI} = \frac{\text{wet meat weight (g)}}{\text{shell cavity volume (ml)}} \times 100.$$

An indication of homogeneity of the means for index values was obtained by calculating the coefficient of variation (CV), which is simply the variance as a percent of the mean (Zar, 1974). The larger the CV, the more heterogeneous (variable) are the data, and the smaller the CV (approaching unity), the more homogeneous are the data.

Two series of water samples for chlorophyll-*a* measurements were collected at each station. However, mishandling during shipment to San Diego caused contamination of the samples, and the measurements were not made.

Results and Discussion

The condition of ten oysters from each station was determined by calculation of the MCI values. Table 2 lists MCI and CV values for July 1974, 1975, and 1976.

Table 2. Comparative oyster condition data for Bangor Annex for sample years 1974, 1975, and 1976.

	1974		1975		1976	
Station	MCI	CV (%)	MCI	CV (%)	MCI	CV (%)
C	58.63	34	50.90	15	59.60	20
E	66.60	19	65.80	22	65.95	11
K	61.46	19	56.50	17	56.46	15
Z	–	–	52.80	18	63.85	11
Toandos Peninsula	–	–	57.90	25	66.73	14

Note: MCI = modified condition index; CV = coefficient of variation; data were not collected at stations Z and Toandos Peninsula in July 1974.

The MCI values at stations E and K are similar from year to year and show little fluctuation. The CV values are also similar, but show a general trend toward a higher degree of homogeneity, that is, lower CV values. The condition of oysters at station E is consistently high when compared with other stations, perhaps because the majority of recreational harvesting for Bangor Annex occurs at that station. *This implies that harvesting results in a lower density of oysters, which may allow more efficient utilization of available resources.*

The MCI values for stations C, Z, and Toandos Peninsula show a definite increase from 1975 to 1976. However, tests for homogeneity of variances (f-test, $P = 0.01$) and means (t-test, $P = 0.01$) indicate that the samples are from the same populations; that is, that the observed variations in MCI values are not significant. As with stations E and K, there is an overall trend toward increased homogeneity, indicated by lower CV values.

Although no fixed limits can yet be placed on normal fluctuations in MCI values, the possibility of recognizing drastic abnormal changes in oyster condition at Bangor Annex is increasing. The continued collection of data coupled with additional sample periods is recommended to improve the baseline data.

BYSSAL THREAD PRODUCTION BY THE COMMON BAY MUSSEL

Introduction

The advantages of using the rate of byssal thread production in mussels to indicate environmental quality were discussed by Peeling and Goforth (1975). Many investigators have demonstrated a relationship between physical-chemical stress and reduced thread production. This relationship has been used to test the relative toxicity of heavy metals and to develop a portable field bio-indicator system employed in San Diego Bay for two years on a regular basis. Racks of 50 mussels are suspended in the water column at a control site and at various treatment sites. If it can be statistically demonstrated that there is no difference

in the rate of byssal thread production between the racks at the control site, differences at the treatment sites can be attributed to differences in water quality. This technique was used during surveys V and VI to assess water quality at the Bangor Annex complex.

Materials and Methods

Mussels were gathered from pilings under Hood Canal Light between depths of approximately -1.0 and -3.0 ft.* The mussels were relatively free of fouling growth, and it was not necessary to scrape them clean. Only those in the range of 35 to 45 mm in length were used, and byssal thread remnants were cut with scissors. Four racks with 50 mussels each, or a total of 200 mussels, were used. All mussels were acclimatized for one week at Hood Canal Light (the control site) before the thread counting series was started. After breaking and counting threads for two days, one rack was left at the light and the others placed at KB Pier, Marginal Wharf, and the explosives handling wharf. Identical procedures were used to obtain thread counts from each station for the next two days. In total, the test consisted of seven days of acclimatization and four days of thread counting.

Heavy metal analyses of mussel tissue were conducted by using procedures recommended by the EPA in "Manual of Methods for Chemical Analysis of Water and Wastes" (1974).

Results and Discussion

The daily thread counts are shown by station in table 3. The chi-square test showed that most sets were normally distributed. Bartlett's test (Zar, 1974) showed that each data set across stations by day had homogeneous variances. Since normality and homogeneity were demonstrated by days, the data were pooled by days. Days one and two were pooled by station (rack) to determine if the racks were equivalent with respect to byssal thread production before they were moved; an analysis of variance (95 percent confidence level) showed that there was no statistically significant difference. An analysis of variance was also performed on the data set for days three and four pooled by station. Again there was no significant difference in the rate of byssal thread production.

These results are almost identical to those from survey V. In 1975, there were no differences detected between racks during the control period or between stations during the treatment period. There was, however, a difference between days. In other words, the rate of byssal thread production changed each day, but the racks also changed similarly. During survey VI, there was no difference among racks during the control period, among stations during the treatment period, or among days at each station. The average thread counts for days three and four, pooled by station for surveys V and VI, are given in table 3. Although there are some slight differences between years at some stations, on the whole the results are very similar. As mentioned previously, there was a daily variation in the rate of byssal thread production during survey V. If thread counts for days three and four are pooled, and then all the stations are pooled, the average for survey V is 25.61 threads per day, and the average for survey VI is 24.65 threads per day. Mean daily thread production during July 1975 and July 1976 thus appears to be essentially the same.

**In survey V, the mussels were collected on the intertidal shoreline approximately 400 meters south of the light.*

Table 3. Mean daily thread production by *Mytilus edulis.*

1976			1975		
Station	Mean	Standard Deviation	Station	Mean	Standard Deviation
Toandos Peninsula			Toandos Peninsula		
Day 1 & 2	24.12	6.87	Day 1 & 2	28.25	8.02
Day 3 & 4	24.79	6.81	Day 3 & 4	25.93	7.53
KB Pier			KB Pier		
Day 1 & 2	23.68	6.34	Day 1 & 2	28.17	8.11
Day 3 & 4	24.43	6.98	Day 3 & 4	26.21	7.33
Marginal Wharf			Marginal Wharf		
Day 1 & 2	25.34	5.36	Day 1 & 2	27.13	7.09
Day 3 & 4	26.42	6.96	Day 3 & 4	24.74	7.60
Explosives handling wharf			Explosives handling wharf		
Day 1 & 2	23.07	7.55	Day 1 & 2	26.45	9.29
Day 3 & 4	25.72	6.49	Day 3 & 4	26.29	9.10

If these data are compared with results obtained for San Diego Bay, the outcome is significantly different. The average for all San Diego Bay thread counts during 1975 and 1976 at all stations for days three and four is 13.61. The mean for Hood Canal is about twice this value. This may be misleading, however, since we have observed a significant seasonal variation in byssal thread production for San Diego Bay but not for Hood Canal. There is a definite peak in thread production in San Diego Bay in July or August and a low thread production period from January through March. It is possible that there is a similar seasonal trend in Hood Canal and that the yearly samplings in July bias the data by presenting the peak rates of thread production. There is no indication, however, that there is an annual significant fluctuation in thread production during the same season.

We have also observed differences in water quality at different stations within San Diego Bay on the basis of byssal thread production rates. In most cases, these cannot be attributed to particular pollutants or groups of pollutants, but in some instances the correlation is clear. For example, one station, the lowest in terms of thread production in five of the ten sampling periods over a two-year period, has the lowest mean daily thread production and the highest concentration of heavy metals in mussel tissues and sediments.

Listed below are the heavy metal concentrations for mussel tissues collected during survey VI. Each sample consisted of 15 to 25 whole mussels excised from the shell; the metal concentrations are presented in mg per kg wet weight.*

**Refer to Peeling and Goforth, 1975, for values reported for 1975.*

Station	As	Cd	Cr	Cu	Hg	Pb	Zn
Toandos Peninsula	<0.03	0.44	0.23	1.7	0.046	0.21	23
KB Pier	<0.03	0.45	0.20	1.8	0.061	0.51	26
Marginal Wharf	<0.03	0.48	0.20	1.5	0.063	<0.02	14
Explosives handling wharf (I)	<0.03	0.31	0.20	1.2	0.043	<0.02	22

The Marginal Wharf samples are consistently low in lead, as were the explosives handling wharf (EHW) samples for 1976. For some unexplained reason, mercury values in 1976 for all stations were lower by approximately a factor of 10 than in 1975. An analysis or calculating error was not found for either year.

On the basis of byssal thread production, the results from surveys V and VI show no difference in stations at various distances from the construction projects. During 1975 there was no construction and only baseline information was collected; however, during survey VI the EHW was nearing completion and extensive clearing of land had been accomplished. Thread production at EHW, where pier construction had been under way since 1975, was not significantly different from that of the other stations. Extensive land clearing for inland building construction had an effect on turbidity within localized areas of Hood Canal, but the rates of byssal thread production did not indicate any unnatural stress.

It should be pointed out that most of the waterfront construction during survey VI was minor and that no significant environmental effects were expected. Thus there should be little difference in the rate of thread production at any station. During two years of pollution monitoring in San Diego Bay and on the basis of significant amounts of data from laboratory toxicity tests, the technique of byssal thread counting has been found to be a valid indicator of stress in mussels. These results also show that the technique is a relatively sensitive one compared to other toxicity tests. The tentative conclusion for Bangor Annex is that all stations are similar with respect to rate of byssal thread production and water quality. Other environmental indicators also show that the stations are relatively clean and unpolluted.

GEODUCK DENSITIES

The relative subtidal density of geoducks (*Panopea generosa*) along Bangor Annex was determined during surveys I through V (Peeling and Goforth, 1975). In review, the subtidal geoduck densities per square meter during July 1975 were

Station	Density (m^2)
A	0
C	1.43
E	1.89
G	0
K	6.69
L	0.50
Z	0.03

To consolidate sampling efforts and dedicate field time to collecting data with the most potential for environmental assessment, geoduck density determinations were limited to stations E and K in July 1976. These stations have had consistently high geoduck density values, and station E will be substantially impacted by waterfront construction.

At each station a color-coded transect line was placed perpendicular to the shoreline; it stretched from approximately the high tide mark out to a water depth of approximately 40 ft. Divers descended a buoy line attached to the deep end of the transect line and recorded their observations over increments of 15 meters while swimming shoreward. Each diver was equipped with a depth gauge, color-code key, and a writing slate with waterproof paper. All geoduck siphons visible within 1 meter of either side of the transect line were counted.

Geoduck densities at station E followed the same distribution patterns as during previous surveys. Specimens were thickly grouped at depths between 30 and 40 ft and thinly scattered at depths extending into the intertidal zone. The calculated density for the area along the transect line in which geoducks occurred in 1976 was $1.29/m^2$. This value is slightly lower than that reported for 1975 but higher than that reported for other seasons of the year (Peeling and Goforth, 1975). The seasonal fluctuation of density values is such that the 1976 data are not significantly different from those of 1975.

An error in the placement of the transect line at station K during survey VI resulted in the counting of geoducks along the shallow side of the area where density is the highest. The calculated density obtained for 1976 was $2.89/m^2$, significantly lower than that reported for 1975 ($6.69/m^2$). However, the same relative density occurred within the same depth ranges from year to year. Therefore, the apparent difference is probably a result of the placement of the transect line and not of an actual reduction in geoduck density.

The dredging to be conducted at station E will reduce to some extent the geoduck population. Any decrease in the salinity of bottom water because of increased flow from the shallow freshwater aquifer may also significantly affect the setting and growth of young geoducks. Therefore, a substantial reduction in geoduck numbers is expected at station E. However, since geoduck juveniles and adults are relatively hardy, the impact on their numbers at other stations along Bangor Annex should be minimal.

MARINE FISHES OF BANGOR ANNEX

INTRODUCTION

The fishes that inhabit the marine environment of Bangor Annex are an important component of the biotic community and must be considered in any environmental assessment program. The species composition, density, and feeding preferences of these fishes affect not only other marine organisms but also human commercial and recreational activities. Emigrating salmon fry that add to the fishery of the entire Pacific Northwest inhabit the shallow waters of Bangor Annex and depend on them as a source of food. Other fishes of importance that inhabit the Bangor Annex area are the rock sole (*Lepidopsetta bilineata*), several species of rockfishes (*Sebastes* spp.), and the lingcod (*Ophiodon elongatus*).

The Fisheries Research Institute of the University of Washington has been intensively studying the dependence of salmonids on Bangor Annex for the Navy. Also, studies have been designed to evaluate and mitigate any impact that waterfront construction might have on these anadromous fishes. The results and conclusions of these studies will be made public through other sources and are thus not included in this report.

To obtain data pertinent to the fishes that inhabit the Bangor Annex vicinity during the summer season, sampling was conducted on 14 July 1976 at eight stations along approximately 9.5 kilometers of shoreline. The results of this sampling, with emphasis on species composition and density, sexual condition, and feeding preferences, are the subject of this section. Also, where applicable, comparisons with previous surveys will be presented.

MATERIALS AND METHODS

Stations A, C, E, G, I, K, L and Z were each sampled by means of a 5-meter spreadboard otter trawl with a cod-end stretch mesh of 13 mm. The trawl was towed for 10 minutes or approximately 600 meters, at a depth of 4–8 meters, corresponding to the deep side of the eelgrass beds present at or near each of the stations.

The contents of stomachs excised from selected specimens of the fishes collected were visually examined for food species composition and abundance. Intestinal contents were not examined because digestion makes identification and enumeration of most food items difficult or impossible. However, the bivalve content of the intestines of two species of flatfishes is worthy of note and will be mentioned later in this section. Sex and gonadal maturity were determined when possible.

Visual inspection of the otter trawl specimens revealed that, as in all previous surveys, the rock soles were heavily infested by the dracunculoid nematode, *Philometra americana*.

RESULTS AND DISCUSSION

Species Composition and Abundance

A total of 14 species of marine fishes representing 9 families were collected in the otter trawls of July 1976. None of these species was new to the cumulative checklist of species for Bangor Annex compiled during surveys I-V. Table 4 lists the species collected during survey VI and their abundance at each station. Most abundant were the tube-snout (*Aulorhynchus flavidus*), an unidentified juvenile rockfish, the copper rockfish (*Sebastes caurinus*), the rock sole (*Lepidopsetta bilineata*), and the shiner perch (*Cymatogaster aggregata*). In the discussion that follows, measurements refer to fork or total length, depending on the species.

It is reported (Hart, 1973) that tube-snouts in British Columbia spawn primarily in April and that hatching occurs primarily in May. The young reach a length of about 51 mm after two months and are commonly seen forming schools in shallow water and near subsurface structures. The tube-snouts collected at Bangor Annex in July ranged in size from 32 to 140 mm, with a mean length of 61 mm, and all were collected in shallow water, most of them in the eelgrass bed at station E. Hart (1973) also reported that tube-snout nests are usually built in water deeper than 10 meters, a point overlooked in surveys I-V. Therefore,

Table 4. Fish species composition and abundance.

Family and Species	Stations A	C	E	G	I	K	L	Z	Total
Gadidae									
Pacific Tomcod (*Microgadus proximus*)		2	1			1			4
Gasterosteidae									
Tube-Snout (*Aulorhynchus flavidus*)		6	72	8	3	3	3	4	99
Embiotocidae									
Shiner Perch (*Cymatogaster aggregata*)		1	3			4	12		20
Striped Perch (*Embiotoca lateralis*)	2	6	7	1					16
Pholidae									
Saddleback Gunnel (*Pholis ornata*)		1	3						4
Scorpaenidae									
Rockfish (juveniles unidentified)		1	24						25
Copper Rockfish (*Sebastes caurinus*)	11	7	2		1	1	1		23
Cottidae									
Pacific Staghorn Sculpin (*Leptocottus armatus*)						1			1
Sailfin Sculpin (*Nautichthys oculofasciatus*)		1							1
Cabezon (*Scorpaenichthys marmoratus*)	3	1						1	5
Bothidae									
Pacific Sanddab (*Citharichthys sordidus*)	1					1			2
Pleuronectidae									
Rock Sole (*Lepidopsetta bilineata*)	7	1			1	8	5		22
English Sole (*Parophrys vetulus*)						1	5		6
CO Sole (*Pleuronichthys coenosus*)						10	2		12
Total	24	27	112	9	5	30	28	5	240

the pattern shown at Bangor Annex of reduced adult tube-snout abundance during April-July, when these fishes have moved into deeper water for spawning, is consistent with that described in the literature. The appearance of young-of-the-year over eelgrass beds in July is also consistent, but the number of individuals collected (99) does not indicate a strong dependence on the Bangor Annex area when compared with the number of adults collected during other times of the year (1,947 in October 1973, 686 in January 1974).

The unidentified juvenile rockfish and the copper rockfish were the second and third most abundant species collected in July. The mean length of the unidentified rockfish was 33 mm and of the copper rockfish 266 mm. De Lacy, Hitz, and Dryfoos (1964) reported that copper rockfish usually give birth in April, and Patten (1973) reported this species reaching maturity at age IV (approximately 250 mm). Ten of the 23 copper rockfish collected in July were subadult, and their presence indicated recruitment of that species at Bangor Annex. Large copper rockfish have consistently been collected at Bangor Annex stations, with the largest (527 mm) being collected in July 1976. Newborn rockfish have been present during surveys in July and October.

The rock sole was the next most abundant species of fish collected at Bangor Annex in July, being much more abundant than during survey V (July 1975), when only four were collected. This does not necessarily indicate a change in environmental conditions, since the rock sole is characterized by marked fluctuations in recruitment from year to year (Forrester and Thomson, 1969). The mean length of the specimens collected was 288 mm, with a range of 137–368 mm. This places the mean age at approximately four years, which is also the age of sexual maturity. Spawning normally occurs between February and April in Puget Sound (Smith, 1936), and young-of-the-year are often seen in shallow water. However, the history of collections at Bangor Annex indicates relatively few specimens of less than 150 mm in length.

The rock sole of Bangor Annex collected during five surveys have shown a consistent and significant infestation by the parasitic dracunculoid nematode *Philometra americana*. The following table indicates the survey by survey occurrence of this parasite:

Rock Sole Collected

Survey	Adults	(Infested)	Subadults	(Infested)
II (Oct. 1974)	9	(5)	3	(0)
III (Jan. 1974)	32	(7)	13	(0)
IV (May 1974)	23	(5)	7	(0)
V (July 1975)	1	(0)	3	(0)
VI (July 1976)	17	(10)	5	(0)
	82	(27)	31	(0)

In no case during the series of surveys at Bangor Annex has a rock sole shorter than 254 mm shown the external red cysts characteristic of *Philometra americana*. However, a study being conducted at the University of Washington (Amish *et al.*, 1976) has shown evidence of infestation in specimens as small as 150 mm in length. Total infestation of rock sole collected at Bangor Annex since October 1973 is 23.9 percent, while infestation of adult

specimens (greater than 254 mm) is 32.9 percent. The percentage of adults infested in July 1976 (58.8 percent) was the highest of any of the surveys. Wingert *et al.* (1976) report infestations of 25–43 percent of the rock sole in other areas of Puget Sound and a significant infestation of other flatfishes as well. No flatfish collected at Bangor Annex, other than the rock sole, has been obviously infested by *Philometra.*

The shiner perch (*Cymatogaster aggregata*) and the striped perch (*Embiotoca lateralis*) have been present along Bangor Annex during all surveys. The piling communities at Marginal Wharf and KB Pier offer excellent food sources, and the extensive eelgrass beds provide protective habitats for the young. Shiner perch are reported to mate during April–July in British Columbia (Weibe, 1968) and to give birth in June–July and occasionally in August (Hart, 1973). Mating in one year is for fertilization of eggs for birth in the following year. Shiner perch are usually 56–73 mm long at birth, 93 mm long at one year, and approximately 136 mm long at six years of age. The specimens collected at Bangor Annex in July 1976 had a mean length of 100 mm, and most had probably just reached their first birthday, though some were at least five years old. A parturition period of August or later for shiner perch in the Bangor Annex area is indicated not only by the absence of newborn in July but also by the presence of these small fishes in January, as recorded during survey III (1974). Newborn striped perch and small young-of-the-year were collected during both July (1975 and 1976) and October (1973), indicating that this species is probably born during May-July.

Stomach-Content Analyses

The stomach contents of 33 fishes representing 5 species were examined for food species composition and abundance. Table 5 shows the percentage of the examined specimens that contained each food item observed. With the exception of the striped perch, there was no distinct restriction in choice of food, although a preference is evident in most cases. Small fishes and crustaceans appear to make up the bulk of the diet for the copper rockfish, with shrimp being preferred. The cabezon (*Scorpaenichthys marmoratus*) showed a general preference for small crustaceans, including the *Cancer* crabs. In addition, two of the cabezon examined contained enough lingcod eggs to cause full distention of their stomachs (one stomach contained 966 grams of eggs). An average of one-third of all the cabezon examined during the surveys at Bangor Annex have contained lingcod eggs in significant amounts, a fact which may have substantial impact on the success of lingcod recruitment in areas of high cabezon density. Also, as observed in previous surveys, a high percentage (greater than 40 percent) of the cabezon examined contained pea gravel and stones. The rock sole and CO sole (*Pleuronichthys coenosus*) examined showed different preferences in choosing food. The CO sole showed a much stronger preference for polychaetes than did the rock sole, while the rock sole ingested small molluscs much more readily than did the CO sole. Both species ate bivalve siphon tips. As mentioned previously, these results are based on stomach contents only and do not represent the contents of the intestines. Small native littleneck clams, butter clams, and cockles (all less than 14 mm long) were present in an additional 26 percent of the rock sole and CO sole if intestinal contents are included. A high concentration of these flatfishes could thus possibly influence the success of commercially important bivalve species in a given area.

Table 5. Results of stomach-content analyses of selected fishes.

Species	Sex (male: female: unknown)	Fish Fragments	Herring (*Clupea harengus*)	Lingcod Eggs	Polychaete Fragments	Marine Worm (*Nephtys* sp.)	Mollusc Fragments	Basket Cockle (*Clinocardium nuttallii*)	Mussel (*Ischadium demissum*)	Moon Snail (*Polinices lewisii*)	Butter Clam (*Saxidomus giganteus*)	Tellen Clam (*Tellina* sp.)	Siphon Tips	Nudibranch	Crustacean Fragments	Skeleton Shrimp (Caprellids)	Ghost Shrimp (*Callianassa californiensis*)	Dungeness Crab (*Cancer magister*)	Red Cancer Crab (*Cancer productus*)	Isopods	Black Clawed Crab (*Lophopanopeus bellus*)	Kelp Crab (*Pugettia producta*)	Shrimp	Brittle Star (Ophiuroids)	Plants (Eelgrass and *Ulva*)	Pea Gravel and Stones	Empty Stomachs
Striped Perch (*Embiotoca lateralis*)	1:1:0																								100		
Rock Sole (*Lepidopsetta bilineata*)	2:7:1		10		50	10	70	10	10		30	10	50		50	10	10			20	10		10	10	30		20
CO Sole (*Pleuronichthys coenosus*)	0:4:1				100								40	20	80								60		60		
Cabezon (*Scorpaenichthys marmoratus*)	2:3:0			40			40			20					80			20	60		20	40			60	40	20
Copper Rockfish (*Sebastes caurinus*)	6:4:1	45	9		18		27	9	9						73				9	9	9		73		45		9

NOTE: Stomach contents presented as the percentage of the designated fish species which contained the food item.

CONCLUSIONS

In July 1976, otter trawl sampling was conducted at eight stations along Bangor Annex. Fourteen species of marine fishes were collected, none of which was new to the checklist of species at Bangor Annex. The following is a list of general conclusions that may be drawn from the results of this portion of survey VI:

1. As observed in surveys I-V, the copper rockfish and the rock sole were the dominant rockfish and flatfish species present along Bangor Annex.

2. The rock sole was more abundant in July 1976 than in July 1975, but there was no indication that this was because of any change in environmental conditions.

3. As in all previous surveys, the rock sole were heavily infested by the nematode *Philometra americana.* Infestation of adult rock sole was 58.8 percent in July 1976, higher than during any other survey period. The total rate of infestation for all survey periods is 23.9 percent.

4. Young-of-the-year specimens of striped perch, rockfish, and tube-snouts were collected in representative numbers.

5. Stomach-content analyses of 33 fishes of 5 species indicated a general diet of small molluscs, crustaceans, and polychaetes. Rockfish showed a preference for shrimp, and rock sole and CO sole a preference for small bivalves; two cabezon specimens examined had stomachs packed with lingcod eggs.

6. A general assessment of these results indicates that conditions at Bangor Annex have not significantly changed since 1975 and that the fish present are healthy and without outward signs of environmental stress.

EELGRASS BEDS OF BANGOR ANNEX

INTRODUCTION

As noted in previous surveys, beds of eelgrass (*Zostera marina*) are almost continuous from the mean low water level to a depth of 15 feet along the entire length of Bangor Annex. Marine grasses, like all grasses, depend on sunlight to provide energy for photosynthesis, but, because they are submerged during most of their life cycle, the problem of light transmittance is significant. Turbid water limits the depth to which eelgrass grows and affects the quality of growth even at shallow depths. Therefore, the condition of eelgrass beds may provide an indication of how the biotic components of the ecosystem are responding to changes in water quality caused by dredging during facility construction at Bangor Annex. Turion density and biomass values were determined during July 1976 for the eelgrass beds at stations A, C, E, G, and K. The results are presented in this section, and the density data are compared with data obtained during surveys IV and V.

MATERIALS AND METHODS

The eelgrass beds at all survey stations were mapped in detail during surveys I and V. Additional measurements were made at stations A, C, E, G, and K during survey VI by divers who determined the position of the bed along a transect line that extended through and beyond the intertidal area. The same magnetic compass course was used to place the transect

line in all surveys, and the measurements obtained thus should indicate relative changes in bed widths.

To obtain more exact turion and biomass data, the sampling procedures of previous surveys were changed. A diver cut off all the visible turions within a 0.1 m^2 area, and they were placed in a sample bag by a second diver for transport to the boat. In this way, turion counts could be made in the laboratory, and the problems of counting in turbid water were avoided. Wide beds (stations E and K) were divided into thirds, and four samples were collected: one each at the shallow and deep sides and one each at one-third and two-thirds of the distance into the bed. Narrow beds (stations E and G) were divided into halves and three samples collected; two samples were collected in the very narrow bed at station C. After the eelgrass had been cleaned of debris and counting completed, the turions were placed in a drying oven at 100°C for approximately 24 hours. After drying, weight measurements were made to obtain standing crop (biomass) values for each sample area within each bed.

RESULTS AND DISCUSSION

Eelgrass turion density and biomass values were obtained for five stations during survey VI. The change in counting procedures and the addition of biomass determinations should provide an improved baseline for accurate estimates of eelgrass response to environmental conditions at Bangor Annex.

Table 6 presents the results of sample collection for survey VI. Minor changes were observed in the width of beds at several stations. In fact, the distance down the transect line at which the eelgrass beds began was shorter at all stations than during survey V. Increases in bed width of 14 and 19 meters were observed at stations E and K respectively. These increases might be attributed to errors in transect line placement, since line length is long at these stations. However, the line was placed carefully, and it is felt that at least part of the difference may be due to a natural increase in bed width. As noted in presenting the results of previous surveys, bed width and contours can be significantly affected by freshwater flow. It is thus possible that changes in the amount and direction of freshwater flow across the beds at stations E and K caused a change in width at the sample points. The bed at station C still consisted of two sparse bands, as noted during survey V.

In general, turion density is greater at the shallow side of eelgrass beds than at the deeper side. Density decreased with depth at all stations except C and A, where the highest density was within the bed rather than at the shallow side. Substrate quality at station C is much less than optimal for eelgrass growth, and abnormal results at this site were not unexpected. The different density distribution at station A should be noted and considered during any future assessment or monitoring program at that station. The rank of stations by mean turion density (number per m^2) in decreasing order is E (1560), A (1180), G (850), K (690), and C (60).

Mean biomass values (grams dry weight per m^2), as expected, followed much the same pattern as turion densities: E (134), A (115), K (73), G (59), and C (27). However, at stations G and K, biomass values became higher as turion densities decreased. At station A, biomass remained relatively constant while turion density fluctuated significantly. Bangor Annex biomass values tend to be low compared with those of from 58 g dry wt/m^2 in March

Table 6. Eelgrass density and biomass data.

Station	Transect Line Distance, m*	Turion Density, no./m^2	Biomass, g dry wt./m^2
A	38	1380	115
	52	1820	112
	66	340	117
C	40	40	23
	58	80	31
E	176	2220	232
	206	2180	122
	236	1680	111
	265	170	69
G	23	1510	48
	37	830	65
	50	200	64
K	197	1050	64
	233	890	91
	269	720	110
	305	110	26

*The first and last distance for each station indicate the shallow and deep sides of the bed respectively.

to 211–226 g dry wt/m^2 in June–August, reported for Denmark by Sand-Jensen (1975), and those of 57–1047 g dry wt/m^2 during spring–summer, reported for Alaska by McRoy (1970).

Harrison and Mann (1975) reported that two forms of *Zostera marina* were present in areas of Nova Scotia: "a) a form with short leaves (up to 18 cm long and 2.5 mm wide) in a dense mat in water less than 1 meter deep, and b) a form with longer, wider leaves (up to 50 cm long and 4 mm wide) which grew in deeper water in soft mud." Phillips (1974) and Rasmussen (1973) suggest that eelgrass may adapt physiologically to local environmental conditions and, in so doing, develop ecological races with differing sensitivities to such conditions as temperature and salinity and differing freedom of movement in currents and tides. Biebl and McRoy (1971) observed morphologically different forms of *Zostera marina* in shallow (tidepool) and subtidal areas. Preliminary studies of eelgrass beds in San Diego Bay, California, conducted by biologists of the Naval Undersea Center, indicate the same types of density and biomass differences as indicated by the literature. Although eelgrass blade lengths have not been measured at Bangor Annex, the turion density and biomass values obtained are consistent with the description given by Harrison and Mann: a dense mat of turions with relatively low biomass (short blades) in the shallower areas of the beds, and a less dense mat with longer, wider blades (higher biomass) in the deeper areas of the beds. Whether or not different races are present along Bangor Annex, the usefulness of determining changes in relative values of turion density and biomass will remain the same. Given the

proper baseline values, changes in environmental quality will be discernible by changes in eelgrass biomass or turion density.

Eelgrass beds are present along almost the entire length of Bangor Annex. The beds appear to be healthy and have not appreciably increased or decreased in size over the last two years. Though biomass values for the five stations studied tend to be lower than those reported for other areas, they probably represent the natural condition of these beds. The condition of the beds should be monitored on a regular basis during construction of new facilities at Bangor Annex, so that any adverse effects may be noticed and corrected, if possible, before irreversible damage occurs.

PILING COMMUNITY STRUCTURES OF BANGOR ANNEX

The use of piling and fouling community composition as a potential indicator of general environmental quality has received much attention (Fischer, 1974). However, as with any potential bioindicator, background data must be compiled so that subsequent changes in species composition or relative density can be attributed to the actual cause: natural, or induced by abnormal stress.

The greatest variability in concentration of piling organisms is expected to occur in the intertidal zone. Temperature extremes, wave action, physical abrasion from floating objects, contaminants (hydrocarbons, detergents, fresh water), and desiccation during low tides all contribute to make the intertidal zone harsher for organism survival than the subtidal zones. This observation has been documented for a variety of marine areas: Pearl Harbor, Hawaii (Evans *et al.*, 1972); Admiralty Inlet, Washington (DePalma, 1976); Monterey Harbor, California (Haderlie, 1968); Los Angeles-Long Beach Harbor (Abbott *et al.*, 1973), and Hamana-Ko Bay, Japan (Kajihara, 1976).

When fouling organisms attach themselves to such subsurface objects as ship's hulls, buoys, and equipment, they can create a significant maintenance problem and often a hazard. These problems can also exist when fouling occurs on pilings and wharf sidings; however, the increased production and availability of food for associated organisms is a distinct advantage. The species composition and available biomass of an area are increased and enhanced by the addition of pilings.

The piling communities at Marginal Wharf (concrete) and KB Pier (wood) were documented during the previous five Trident surveys to quantify species composition and numerical densities. This effort was duplicated during survey VI, and fouling on the concrete pilings at the new explosives handling wharf (EHW) was also observed. Two divers, equipped with a color-coded transect line for depth determinations, a 35-mm camera with strobe, depth gauges, and underwater slates with paper, recorded species composition, zonal distribution, and general observations for representative pilings at each study area. Results showed that the communities at both Marginal Wharf and KB Pier remained essentially unchanged from those reported by Peeling and Goforth (1975).

The driving of piles for the EHW started in July 1975 and was finished before July 1976. However, no appreciable amount of fouling had occurred by the time of survey VI. The center concrete pilings contained the empty brittle shells of many barnacles that had

settled but had not survived. Fresh concrete is toxic because of its high alkalinity and might be the cause of this mortality. A rapid fouling growth of barnacles and other organisms will probably occur on the pilings as the pier is completed and the pilings become "seasoned."

It is believed that sampling the fouling communities at each piling station will provide highly useful, quantitative, and comparable data for preconstruction and postconstruction monitoring of conditions at Bangor Annex. It is recommended that collections (15 by 30 cm) be taken quarterly at 2-meter intervals, or in each biotic zone, from the surface to the bottom of the piling for each station. At least three pilings from each pier area should be sampled. These samples should then be analyzed for species composition, densities, and biomass (dry weight per sample area). Documentation of the free-swimming fishes and mobile invertebrates associated with the piling structures should be included. In this way, the contribution to the ecosystem by the piling community can be quantified and its value understood.

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APPENDIX. CUMULATIVE CHECKLIST OF MARINE ORGANISMS

A cumulative checklist of all organisms identified during six marine environmental surveys at Bangor Annex, Hood Canal, Washington, is contained in this appendix. The format consists of a phyletic (taxonomic) listing which includes a numeric (10 digit) identification code (see below) for each organism in the checklist. Additionally, the naming authority and date of naming are listed, where available.

The Hawaii Coastal Zone Data Bank (HCZDB) is currently maintained at the University of Hawaii and contains a comprehensive listing of more than 9,000 species of organisms recorded from the Pacific basin. Utilizing a five-diad computer identification number permits rapid storage and retrieval of taxonomic data. The numbers are assigned to various taxonomic levels as follows:

Digits	Taxonomic level
1, 2	Phylum (Subphylum)
3, 4	Class and order
5, 6	Family
7, 8	Genus
9, 10	Species (subspecies)

For example: Ta

Number	Taxon
68	Phylum – – – – –
681	Class – – – – –
6811	Order – – – – –
681101	Family – – – – –
6811010101	Genus and species

As an interim procedure, "X's" are placed in the checklist for a newly encountered species. This indicates that the number has not yet been assigned and is required at the specified taxonomic level (e.g., 6902XXXXXX requires family, genus and species numeric assignments). Ending "00's" indicate the level to which the organism has been identified (e.g., 6905040300 has been identified to the generic level).

The cumulative checklist contains 400 species of Hood Canal marine organisms: 188 floral species (from 44 families) and 212 faunal species (from 115 families). This study has expanded the HCZDB master list by 135 species: 80 algal species and 55 faunal species.

CUMULATIVE CHECKLIST OF BANGOR ANNEX MARINE BIOTA (HOOD CANAL, WASHINGTON)

FLORA

TAXA	HCZDB NO.
Chlorophyta	
Chlorophyceae	
Ulotrichales	
Monostromaceae	
Monostroma oxyspermum (Kutzing) Doty, 1947	0413150101
Monostroma fuscum (Postels & Ruprecht) Wittrock	04131501XX
Ulvaceae	
Enteromorpha clathrata (Roth) Greville, 1830	0413160102
E. tubulosa Kutzing, 1856	0413160106
E. compressa (Linnaeus) Greville, 1830	0413160107
E. linza (Linnaeus) J. Agardh, 1883	0413160113
E. intestinalis v. cylindracea (Linnaeus) Link,1820	04131601XX
E. intestinalis v. intestinalis(Linnaeus) Link,1820	04131601XX
E. compacta	04131601XX
Enteromorpha sp.	04131601XX
Ulva lactuca Linnaeus, 1753	0413160202
U. rigida C. Agardh, 1822	0413160204
U. latissima	0413160209
U. vexata	04131602XX
Ulva sp.	0413160200
Cladophorales	
Cladophoraceae	
Cladophora sp. A	04180101XX
Cladophora sp. B	04180101XX
Chaetomorpha californica	04180102XX
C. canabina	04180102XX
Rhizoclonium riparium (Roth) Harvey, 1849	0418010303
Siphonales	
Codiaceae	
Codium setchellii Gardner, 1919	0421050211
Chrysophyta	
Bacillariophyceae	
Centrales	
Biddulphiaceae	
Biddulphis grundleri Hendy	0741010105
B. obtusa (Kutzing) Ralfs.	0741010106
Biddulphia sp. A	0741010100
Coscinodisaceae	
Coscinodiscus lineatus Ehrenberg	0741060103
C. marginatus Ehrenberg	0741060104
C. obscurus	07410601XX
C. tabularis	07410601XX
Coscinodiscus sp. DTB	07410601XX
Coscinodiscus sp.	0741060100
Melosiraceae	
Melosira moniliformis (O. F. Muller)	0741070102

Chrysophyta	
Bacillariophyceae	
Centrales	
Thalassiosiraceae	
Thalassiosira pseudonana	07410901XX
Thalassiosira sp. DTE	07410901XX
Thalassiosira sp. DTI	07410901XX
Pennales	
Fragilariaceae	
Fragilaria virescens Hendey	0742010101
F. pinnata	07420101XX
Rhaphoneis surirella	0742010232
Opephora sp. DTE	07420104XX
Synedra tabulata	0742010531
S. fasciculata	07420105XX
S. pulchella	07420105XX
Synedra sp. (short)	07420105XX
Licmophora abbreviata Agardh	0742010701
L. flabellata (Greville) Agardh	0742010704
Licmorpha sp. 1	07420107XX
Grammatophora oceanica	0742010831
Grammatophora sp.	0742010800
Tabellariaceae	
Rhabdonema substratum	074202XXXX
R. torelli	074202XXXX
Cymbellaceae	
Amphora angusta Gregory	0742060102
A. coffaeiformis (Agardh) Kutzing	0742060106
A. cymbifera Gregory	0742060107
A. exigua Gregory	0742060108
A. macilenta Gregory	0742060112
A. proteus Gregory	0742060115
A. elegans	07420601XX
A. perstriata	07420601XX
A. pusio	07420601XX
A. staurophora	07420601XX
Amphora sp. DTE-1	07420601XX
Amphora sp. DTK-A	07420601XX
Amphora sp.	07420601XX
Naviculaceae	
Navicula abunda Hustedt	0742070102
N. crucigera (Wm. Smith) Cleve	0742070111
N. diversistriata Hustedt	0742070114
N. grevilleana (Agardh)	0742070119
N. pennata Schmidt	0742070128
N. directa var.	0742070155
N. apta	07420701XX
N. assula	07420701XX
N. littorica	07420701XX
N. salinarum	07420701XX
Navicula sp. (small)	07420701XX
Navicula sp. A	07420701XX

Chrysophyta	
Bacillariophyceae	
Pennales	
Naviculaceae (continued)	
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G. corymbifera (Kutzing) J.G. Agardh, 1876	1324200108
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